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Depth of straw incorporation significantly alters crop yield, soil organic carbon and total nitrogen in the North China Plain

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ABSTRACT

Appropriate straw incorporation has ample agronomic and environmental benefits in the North China Plain, but most studies are limited to straw mulching or incorporation on the soil surface. To determine the effect of depth of straw incorporation on crop yield, soil organic carbon (SOC) and total nitrogen (TN), a 3-year field experiment was established with the following four treatments: (i) no straw incorporation (CK); (ii) straw incorporation at 15 cm (S15); (iii) straw incorporation at 25 cm (S25) and (iv) straw incorporation at 40 cm (S40). The results showed that straw incorporation significantly increased SOC, TN and C:N ratio ($P < 0.05$). Compared with CK, substantial increases ($P < 0.05$) in SOC and TN were observed at the 0-20 cm layer under S15, at all depths under S25 and at the 40-60 cm depth under S40. Under S25 (20-40 cm) in particular, the SOC and TN levels considerably ($P < 0.05$) exceeded those under CK (8.83˜17.26% of SOC and 6.28˜10.25% of TN), S15 (3.66˜9.25% of SOC and 2.13˜4.70% of TN) and S40 (4.74˜8.23% of SOC and 3.21%˜4.27% of TN). The average SOC and TN at 0-60 cm under S25 was also significantly higher ($P < 0.05$) than those under S15 and S40. Straw incorporation also increased the C:N ratio and the response of C:N ratio to straw incorporation differed by the depth of straw incorporation and the soil layer. Compared with S15 and S40, S25 had a significant effect on the C:N ratio at each soil layer. Both S25 and S40 decreased the stratification ratio (SR) of SOC, TN and C:N ratio and promoted a uniform distribution of SOC and TN within the 0-60 cm depth. Compared with CK, straw incorporation also significantly increased ($P < 0.05$) crop yields, especially under S25, by 10.83% in 2014, 13.25% in 2015 and 7.68% in 2016. The grain yields of wheat and maize were positively correlated with SOC and TN (0-20 cm and 20-40 cm). Thus, in the North China Plain, straw incorporation at the 25 cm depth would boost soil fertility and crop yield.

1. Introduction

Soil organic carbon (SOC) is the core of soil quality and is critical to food production and security (Huang et al., 2015; Lal, 2004; Zhao et al., 2018). SOC sequestration in arable soils is of great significance in mitigating greenhouse gas emissions and improving climate conditions (Buyanovsky and Wagner, 1998; Lu et al., 2018; Schlesinger and Amundson, 2018). The relationship between crop and soil nitrogen is also very close, and nitrogen deficiency in soils will lead to yield reduction (Wang et al., 2008; Zhang et al., 2018b). The distribution of soil nutrients in the soil profile affects the growth of crop roots and the uptake of nutrient (Thorup-Kristensen et al., 2012).

Soil quality cannot be assessed only from the content of nutrients, but also from the distribution in the soil layer. Most studies showed that SOC tend to decrease with increases in soil depth (Cui et al., 2018; Hernanz et al., 2002). The distribution of nutrients in soils is not uniform; generally, SOC is the highest in the topsoil (De Oliveira Ferreira et al., 2013; Pan et al., 2010). Franzluebbers (2002) proposed the stratification ratio (SR) of SOC fractions to describe the distribution of SOC in soil, and SR shows the relationship between SOC at top soil layer and SOC at deep soil layer. SR was not affected by soil type and climate and it can be used as an index of soil quality dynamics (Franzluebbers, 2002; Zhang et al., 2015). The structure and fertility of topsoil are crucial to the sustainable development of agriculture, so it is generally believed that value of SR of SOC is lower (< 2.0) in degraded soils (De Oliveira Ferreira et al., 2013; Melero et al., 2012). But in recent years, SOC and TN at deep soil layer have attracted the attention of researchers (Han et al., 2018; Modak et al., 2019). Soil nutrient

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