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Soil C/N and pH together as a comprehensive indicator for evaluating the effects of organic substitution management in subtropical paddy fields after application of high-quality amendments

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ABSTRACT

Organic substitution management (OSM) is a key technology employed to reduce the amount of chemical fertilizer used in agricultural operations with the goal of reducing environmental pollution and ensuring green and sustainable agricultural development in China. However, there is still limited information regarding the underlying interactions between soil nutrients, enzyme activities and microbial community structures after long-term partial substitution of inorganic N with organic amendments, and no suitable evaluation indicators of organic substitution effects have been identified. Here, distance-based redundancy analysis (dbRDA), principal component analysis (PCA), the partial least squares method (PLS) and the partial least squares path model (PLS-PM) were used to better understand the impact of substitution effects on soil biochemical indexes in a 34-year field experiment. We found that soil C/N significantly directly affected rice yield, and that a soil C/N ranging from 10.12 to 10.19 could sustain a rice yield between 7000 and 6800 kg ha^{-1}. Moreover, the soil hydrolase activities of the carbon and fungi communities were significantly influenced by both C/N and pH, and the carbon-cycling enzyme activities were found to be more susceptible to C/N than nitrogen-cycling enzyme activities. The low soil C/N and high pH after OSM decreased the ratio of G^+ to G^- and fungi to bacteria, indicating OSM increased the nutrient availability and benefited growth of the bacterial community. Hence, we believe that soil C/N and pH together can be used as a comprehensive index for suitable evaluation of the effects of OSM.

1. Introduction

Fertilizer generally increases food production by 40%–60%, making it crucial to ensuring food security worldwide (Stewart et al., 2005). Indeed, nearly half of the world's population is supported by Haber-Bosch nitrogen fertilizer (Erisman et al., 2008). However, nitrogen fertilizer may represent an Achilles heel of modern agricultural production owing to the degree of its misuse (Falcon et al., 2012). Moreover, environmental problems caused by the excessive application of nitrogen (Zhang et al., 2011; Sutton et al., 2013), such as eutrophication, emission of greenhouse gases, and decreased biodiversity, have become great concerns to countries around the world, especially China. Therefore, many studies to develop methods of ensuring food security and achieving green and sustainable agriculture while reducing the amount of chemical fertilizer needed are currently being conducted in China.

Strengthening agricultural technological innovations can contribute to production of more food without increasing environmental pressure (Sayer and Cassman, 2013). Substitution of organic amendments for inorganic fertilizer is one of the key technologies utilized to reduce the amount of chemical fertilizer applied and increase its efficiency (Zhou, 2017). At present, approximately 5.7 billion tons of organic resources are produced annually in China, equivalent to about 30 million tons of N, 13 million tons of P_2O_5, and 30 million tons of K_2O (Niu et al., 2017). However, it is estimated that only 4.84 million tons of N, 4.11 million tons of P_2O_5, and 12.73 million tons of K_2O return to cropland (Li et al., 2017). Hence, substitution of organic amendments for chemical fertilizer will achieve a win-win situation for reducing ecological

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