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# Co-incorporation of green manure and rice straw improves rice production, soil chemical, biochemical and microbiological properties in a typical paddy field in southern China

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ABSTRACT

The cultivation of green manure or rice straw returns in southern China increases crop yields and soil fertility. Few studies have reported the effects of combining both management techniques on rice performance and soil fertility. A 3-year field study was carried out to analyse the impacts of the co-incorporation practice on soil microbial and biochemical parameters as well as crop yield. Five treatments were tested: (i) no-fertilizer (CK); (ii) chemical fertilizer (F); (iii) F plus green manure (FM); (iv) F plus rice straw (FS); (v) F plus green manure plus rice straw (FMS). The results showed that incorporation of green manure and/or rice straw increased double rice yields by 4.1% (FM), 4.7% (FS) and 9.6% (FMS) compared with F. The FMS treatment enhanced soil organic C (SOC), total N (TN), mineral N ($N_{min}$), and available K (AK) levels by combining the advantage of FM in increasing TN and $N_{min}$ and the advantage of FS in increasing SOC and AK in comparison with F. The incorporation of green manure and/or rice straw stimulated microbial growth (total phospholipid fatty acids, PLFAs) and altered the soil microbial community structure relative to F, in which FMS had the greatest effect. The enzyme activities of β-glucosidase, β-cellobiosidase, *N*-acetyl-glucosaminidase, L-leucine aminopeptidase and phosphatase were higher in the green manure and/or rice straw application treatments than in the F treatment in the order FM ≈ FS < FMS. The partial least squares path model (PLS-PM) analysis indicated that green manure mainly influenced the abovementioned indices in the early rice season, while the effects of rice straw lasted until the late rice season. Our results suggest that co-incorporation of green manure and rice straw is a more effective practice for improving soil fertility and rice yields.

## 1. Introduction

Enhancing crop productivity to feed the world's increasing population and maintain high living standards has become a great challenge (Fischer et al., 2014). Unfortunately, agriculture must also address tremendous environmental concerns, compounding this challenge. For instance, numerous studies have confirmed that the excessive application of chemical fertilizer is now a dominant force behind many environmental threats, such as soil degradation and freshwater eutrophication (Sutton et al., 2013). Therefore, many studies are developing methods that will achieve a win-win situation for ensuring food security and shrinking agriculture's environmental footprint.

Green manure cultivation and rice straw return can contribute to the production of more food without increasing chemical fertilizer applications (Nawaz et al., 2017; Xia et al., 2018; Yang et al., 2019), and can also alleviate the soil degradation caused by intensive and continuous conventional tillage (Lou et al., 2011). Green manure from legumes can provide N to soils through biological N fixation and can then increase the soil N supply to subsequent crops (Thorup-Kristensen et al., 2003). However, leguminous green manure with high N concentrations

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