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Responses of extracellular enzyme activities and microbial community in both the rhizosphere and bulk soil to long-term fertilization practices in a fluvo-aquic soil

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ABSTRACT

The influence of inorganic or organic fertilization on soil microbial ecology has been emphasized recently, but less is known about rhizosphere effects on extracellular enzyme activities and microbial community structure. Eleven extracellular enzymes involved in C, N, P, and S cycling and microbial community structure in both the rhizosphere and bulk soil samples from a long-term (31-year) fertilizer experimental field at the wheat reproductive stage were investigated by microplate fluorometric assay and phospholipid fatty acid analysis (PLFA), respectively. The samples were taken from six treatments: control (CK, without fertilization), fertilizer N (N), fertilizer N and P (NP), fertilizer N, P and K (NPK), organic manure (M), and organic manure plus fertilizer N, P and K (MNPK). Responses to inorganic or organic fertilizers in the rhizosphere were significantly different from those in the bulk soil. Except for NO_3^--N, thus, nutrient concentrations were generally higher in the rhizosphere than in the bulk soil. M and MNPK treatments greatly increased organic C, total N, NH_4^+-N and total S. Inorganic fertilizers (N, NP, and NPK) generally maintained or reduced most enzyme activities in the rhizosphere, but markedly increased these enzyme activities in the bulk soil. However, organic treatments (M and MNPK) enhanced most enzyme activities in both the rhizosphere and bulk soil. Higher total PLFA and lower ratios of bacteria to fungi and of actinomycetes to fungi were observed in the rhizosphere compared with the bulk soil. In the bulk soil, the ratios of bacteria to fungi and of actinomycetes to fungi were highest in the N treatment and lowest in the M treatment. However, in the rhizosphere there were no statistically significant differences in the abundance of bacteria, fungi and actinomycetes between the inorganic and organic treatments. Organic fertilization increased total PLFA and Gram+ to Gram− bacteria ratio in both the rhizosphere and bulk soil. Our results indicated that changes in fertilization regime had a greater impact on the bulk soil microbial community than in the rhizosphere.

1. Introduction

The rhizosphere, the volume of soil adjacent to and affected by plant roots (Sørensen, 1997), plays an important role in plant growth and soil fertility (Rovira, 1969). As soil microbes are often limited by energy in soils, root exudates such as organic acids, sugars and amino acids may stimulate the growth of microbial populations and the activities of extracellular enzymes capable of influencing biogeochemical cycling of C, N, P and S (Fontaine and Barot, 2005; Rovira, 1969; Stevenson and Cole, 1999). Fertilization, which is widely used to enhance soil fertility and crop yield, significantly affects soil biochemical and biological properties. The influence of fertilization on soil microbial ecology has been emphasized recently (Marschner, 2003; Yevdokimov et al., 2008; Zhong et al., 2010). However, most investigations have been conducted at a bulk soil scale or in short-term experiments, and as a result, there is still little available information on rhizosphere effects on extracellular enzyme activities and microbial community structure in agricultural soils as influenced by long-term practices.

From a functional perspective, the activities of extracellular enzymes produced by both microbes and plant roots are the primary biological mechanism of organic matter decomposition and nutrient cycling (Wittmann et al., 2004). Organic matter addition often leads to a rapid increase in the activities of various enzymes and reactivation of biogeochemical cycles in bulk soil (Bastida et al., 2007; Madejon et al., 2001). Inorganic N, P and K fertilizers also impact on the activities of soil enzymes (Böhme et al., 2005; Goyal et al., 1999). Most hydrolytic enzyme activities were increased by addition of N fertilizer in a forest soil, but the phenol oxidase activity dropped 40% compared to control plots (Saiya-Cork et al., 2002). Weand et al. (2010) emphasized that the effect of added N on enzymatic activities in a soil changes depending on the nature of the dominant substrates (labile or recalcitrant). Compared to numerous studies on enzyme activity in bulk soil, less effort has been expended on determining how long-term fertilization affects rhizosphere

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