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Characteristics of maize biochar with different pyrolysis temperatures and its effects on organic carbon, nitrogen and enzymatic activities after addition to fluvo-aquic soil

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HIGHLIGHTS

- Pyrolysis temperature markedly influenced characteristics of maize biochar
- Maize biochar addition to soil increased soil organic C and total N contents
- Soil NO_3^--N content increased and then reduced with increasing pyrolysis temperature
- Biochar pyrolysis temperature influenced extracellular enzyme activity

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ABSTRACT

In this study, the characteristics of maize biochar produced at different pyrolysis temperatures (300, 450 and 600 °C) and its effects on organic carbon, nitrogen and enzymatic activities after addition to fluvo-aquic soil were investigated. As pyrolysis temperature increased, ash content, pH, electrical conductivity, surface area, pore volume and aromatic carbon content of biochar increased while yield, ratios of oxygen:carbon and hydrogen: carbon and alkyl carbon content decreased. During incubation, SOC, total N, and ammonium-N contents increased in all biochar-amended treatments compared with the urea treatment; however, soil nitrate-N content first increased and then decreased with increasing pyrolysis temperature of the applied biochar. Extracellular enzyme activities associated with carbon transformation first increased and then decreased with biochars pyrolyzed at 450 and 600 °C. Protease activity markedly increased with increased pyrolysis temperatures, whereas pyrolysis temperature had limited effect on soil urease activity. The results indicated that the responses of extracellular enzymes to biochar were dependent on the pyrolysis temperature, the enzyme itself and incubation time as well.

1. Introduction

Biochar is produced by the pyrolysis of organic material under oxygen-limited conditions and at relatively low temperatures (<700 °C). As there are differences in raw materials, pyrolysis conditions and the technical processes of biochar production, the resultant biochars embody various physicochemical and biological characteristics (Yuan et al., 2011; Bergeron et al., 2013; Mimmo et al., 2014). The physicochemical characteristics of biochar, such as elemental composition, pore structure, specific surface area and ash content are significantly influenced by both the raw material of biochar and its pyrolysis temperature (Ronsse et al., 2013; Wiedner et al., 2013). In particular, pyrolysis consists of a series of complex reactions that can be divided into three stages according to the degradation temperatures for hemicelluloses (220–315 °C), cellulose (315–400 °C) and lignin (>400 °C) (Yang et al., 2006). As a consequence, it is crucial to characterize biochar produced at different pyrolysis temperatures with appropriate analytical processes to acquire information on the biochar chemical and physical characteristics, which can be associated with biochar stability and agronomic benefits. Agricultural residues, such as rice straw, hazelnut shell and orange peels, are representative of low cost biomass resources used for generating biochars (Lou et al., 2011; özçimen and Ersoy-Meriçboyu, 2010). Maize straw is very common in China and might be valuable for biomass production; however, little information is available on the characteristics of maize biochar produced under various pyrolysis temperatures.

Biochar application can affect a number of soil biogeochemical processes, especially carbon (C) and nitrogen (N) cycling (Nelissen et al.,

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