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Spatio-temporal distribution of rhizosphere enzyme activities in heavy metal-contaminated soil as affected by manure and its biochar application

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Chromium (Cr) contamination is especially hazardous to soil biota. Application of manure and the biochar from manure has been proposed as noteworthy strategy to remediate Cr-contaminated soil. However, the mechanisms' understanding of manure and biochar impacts on soil microbial activities requires advanced visualization technologies. For the first time, we compared manure and its biochar influence on spatio-temporal distribution of the activities of three enzymes (i.e. β-glucosidase, N-acetyl-glucosaminidase and phosphomonoesterase) in Cr-contaminated acidic soil over 45 days. In-situ zymography was used to identify the spatio-temporal distribution of enzyme activities. Maize was planted in: (a) soil homogenously mixing with cow manure (Man); (b) soil with homogeneously mixing manure-derived biochar (Bio); and (c) a control soil without any addition (Con). Soil pH drastically decreased during 30 days leading to strong increase of acid soluble Cr. The concomitant decrease of β-glucosidase and N-acetyl-glucosaminidase activities was the main mechanism for narrowing the rhizosphere extent of enzyme activities by 21-45%. This indicates that increased Cr bioavailability decreases microbial activities. Biochar application had larger liming effect compared with manure addition. Larger Cr tolerance index of maize and highest shoot/root ratio after biochar application indicated enhanced plant tolerance to Cr stress. In contrast, manure application induced the smallest shoot/root ratio ($\sim$0.87<1.0), suggesting that manure application caused a wasteful competition between plant and microbes. Besides, manure application narrowed more the rhizosphere and hotspots extent of β-glucosidase and phosphomonoesterase activities compared to biochar addition. This narrowest extent was attributed to the addition of labile organic compounds and nutrients following manure application. Our study emphasizes the importance of soil pH for remediation of Cr-contaminated soil using organic fertilizers and demonstrates that biochar application is a better management option than its feedstock for plant growth and microbial activities.
KEYWORDS: Soil zymography, Heavy metal contamination, Enzyme activities, Manure, Biochar, Rhizosphere

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