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Microbial mechanisms responsible for the variation of soil Cd availability under different pe+pH environments

Meng Wang [a], Shibao Chen [a,*], Li Chen [b], Duo Wang [c]

[a] Key Laboratory of Plant Nutrition and Fertilizer, Ministry of Agriculture and Rural Affairs / Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing, 100081, PR China
[b] Institute of Plant Protection and Environmental Protection, Beijing Academy of Agriculture and Forestry Science, Beijing, 100097, PR China
[c] College of Energy, Xiamen University, Xiamen, Fujian, 361102, PR China

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ABSTRACT

The objective of this study was to explore potential microbial mechanisms associated with how water management may alter soil Cd availability under changing pe + pH environments. Four water regimes, aerobic [70% MWHC] + dissolved oxygen, aerobic, continuous flooding, and continuous flooding + N_2, were applied to Cd-contaminated soil. The results show that the anoxic treatments were effective in decreasing soil pe + pH and in turn decreased Cd availability and increased soil S and Fe availability relative to those of the aerobic treatments. The decreased pe + pH enriched some anaerobic microorganisms such as those in the families *Anaerolineaceae* and *Geobacteraceae*. Conversely, other families, such as *Gemmatimonadaceae* and *Sphingomonadaceae*, appeared to be sensitive biomarkers that responded to aerobic treatments. Bacterial community structure and network interactions were altered to strengthen bacterial responses to different pe + pH environments as indicated by phylogenetic molecular ecological network (pMEN) analysis. The majority of predicted functional categories, such as metabolism, cell motility, and membrane transport, were affected by different irrigation regimes as indicated by a functional gene profile analysis. The categories were related to important traits that facilitated acclimation of bacteria to their local environment with altered soil pe + pH. Structural equation models revealed that soil pe + pH contributed significantly to soil enzyme activities and differences in bacterial community and function, and consequently, was responsible for the variation of soil Cd availability and iron or sulfur reduction.

1. Introduction

Soil cadmium (Cd) contamination is increasingly a serious problem in agronomy due to uncontrolled mine exploration, unsustainable urbanization, and intensive agricultural practices (Jiao et al., 2006; Zheng et al., 2019). Among the remediation strategies (application of soil amendments, improving water and fertilizer management, and sowing cultivars with limited-Cd accumulation, as well as other tillage management strategies), better water management is one of the most commonly selected and economical practice for alleviating Cd contamination, especially in paddy soils (Honma et al., 2016; Zheng et al., 2019). Furthermore, it is often selected because soil moisture regime plays a critical role in affecting soil properties, which in turn influence the mobility of Cd via transformations in its speciation (Li and Xu, 2017; Han et al., 2018). For instance, soil Cd is redistributed from the exchangeable form to iron-manganese (Fe–Mn) oxide-bound form in flooded soils owing to the adsorption capacity of hydrous Mn and Fe oxides to Cd, resulting in decreased Cd availability to plants (Zhu et al., 2012).

When a paddy field is subjected to hypoxic (partially drained) conditions, the gas exchange between the atmosphere and soil can be reinforced, which allows aeration to generate diverse electron acceptors in the soil (Miao et al., 2015). Contrarily, anoxic (flooded) conditions promote a much reduced wetland environment (Zheng et al., 2019). Generally, the alternating hypoxic and anoxic conditions is generated with uncertain fluctuations in the water level of the paddy soil, which leads to variations in soil geochemical properties (Jiao et al., 2006; Sun et al., 2019). Soil redox potential (Eh) is considered a sensitive parameter to water management. Flooding toward a reduced state heavily decreases soil Eh between +500 and +700 mV and −200 to −300 mV

* Corresponding author. No. 12 Zhongguancun South Street, Beijing, 100081, PR China.
E-mail address: chenshibao@caas.cn (S. Chen).

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