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ORIGINAL PAPER

The alleviation of acid soil stress in rice by inorganic or organic ameliorants is associated with changes in soil enzyme activity and microbial community composition

Chao Ai · Guoqing Liang · Jingwen Sun · Ping He · Shuanhu Tang · Shaohai Yang · Wei Zhou · Xiubin Wang

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Abstract The effects of calcium-magnesium phosphate, rock phosphate, lime, fly ash, and animal manure as liming agents on the microbial community composition, enzyme activities involved in C, N, P, and S cycling and rice yields of acid sulfate soils were studied in a three-year field trial. Significant increases in soil pH caused by five ameliorants, particularly lime and fly ash, were observed after 3 years. Both soil exchangeable Al^{3+} and H^+ were significantly ($P<0.05$) and negatively correlated with soil pH. Increased pH led to 61–102 % increase in rice yield after 2 and 3 years but not after 1 year. Soil phospholipid fatty acid (PLFA) profiles and enzyme activities were significantly changed after 3 years of application of the soil amendments. Enzyme activities increased along gradients of soil pH, indicating that the influences of inorganic or organic ameliorants on soil enzyme activities were mainly due to the effect on soil pH value. PLFA analysis showed that this pH effect played a more important role in shaping microbial community composition than specific effects of organic and inorganic amendments. All rice yield-associated enzymes and PLFA biomarkers (e.g., gram-negative bacteria and actinomycetes) were regulated by soil pH after 3 years. These results revealed that pH-induced changes in soil enzyme activity and microbial composition might be an important mechanism in alleviating acid stress in soil cropped to rice by various ameliorants.

Keywords Acid sulfate soil · Ameliorants · Microbial community composition · Rice · Soil enzyme activity · Soil pH

Introduction

Acid soils (pH≤5.5) are distributed worldwide and present in approximately 30 % of the world's ice-free land area (Kochian et al. 2004). Productivity of acid soils is generally low because of their low available P, Mg and Ca, and presence of phytotoxic Al concentrations (Barman et al. 2013; Qian et al. 2013; Shazana et al. 2013). Acid sulfate soils cover an area of 17–24 million hectares worldwide and are mainly located in tidal swamps and coastal plains of Asia, eastern Australia, Latin America, and Africa (Dent and Pons 1995; Fältmarsh et al. 2008). The main characteristic of acid sulfate soils is that they contain abundant sulfide minerals, predominantly pyrite (FeS_2). When exposed to the air, pyrite oxidation resulted in the formation of sulfuric acid, which lowers soil pH as low as 3.5 and also leads to the occurrence of Fe and Al toxicity (Shazana et al. 2013). In addition to low pH, low P availability is another major limiting factor in acid sulfate soils (Lin et al. 2001) because it often forms insoluble complexes with cations such as Al and Fe. Rice yield in acid sulfate soils is as low as 1.5–3.0 t ha^{-1} (Husson et al. 2000; Tinh et al. 2001).

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C. Ai · G. Liang · J. Sun · P. He · W. Zhou (✉) · X. Wang (✉)
Ministry of Agriculture Key Laboratory of Plant Nutrition and Fertilizer, Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, People's Republic of China
e-mail: wzhou@caas.ac.cn
e-mail: wangxb@caas.ac.cn

P. He
International Plant Nutrition Institute China Program, Beijing 100081, People's Republic of China

S. Tang · S. Yang
Institute of Agricultural Resources and Environment, Guangdong Academy of Agricultural Sciences, Guangzhou 510640, People's Republic of China

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