Phosphorus sorption characteristics in acid sulfate soils of Thailand: Effect of uncontrolled and controlled soil redox potential (Eh) and pH

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Abstract

Two laboratory experiments were conducted to study phosphorus sorption characteristics in acid sulfate soils (para- and actual-acid sulfate soils) of Thailand. In one experiment the soils were subjected to oxidized and reduced conditions, in another they were maintained under different controlled pH (4.0, 5.0, and 6.0) and Eh (+600, +400, +300, +200, +100, and 0 mV) conditions. In both experiments the soils were kept in stirred suspensions with a soil to 0.01 M CaCl₂ solution ratio of 1:7 for 6 weeks. After the incubation period, the soil suspensions were equilibrated with KH₂PO₄ ranging from 0 to 500 mg P kg⁻¹ soil. Sorption isotherms were described by the classical Langmuir equation. The results from the first experiment showed that more native insoluble P was released under reduced than oxidized conditions, with more being released from para-acid sulfate soil than from actual acid sulfate soils. Soil reduction also caused an increase in P-sorption. Less P-sorption occurred under both conditions in para-acid sulfate soil than in actual acid sulfate soils. In the second experiment, the P-sorption of both actual and para-acid sulfate soils was significantly affected by soil Eh, pH, and their interactions. The P-sorption increased significantly with increasing pH and decreasing Eh. At pH 4.0, a considerable increase in P-sorption occurred as Eh decreased from +400 to +300 mV, whereas at pH 5.0 and 6.0 an obvious change in P-sorption occurred when Eh decreased from +300 mV to +200 mV. The actual acid sulfate soil sorbed more P than did para-acid sulfate soil. Significant correlation between P-sorption parameters and iron-oxides indicated the primary role of iron-oxides in P-sorption of acid sulfate soils of Thailand. Aluminum-oxides seemed to play a secondary role in P-sorption of these soils. Manganese also showed a significant effect on P-sorption.

Introduction

Thailand is one of the major rice production countries in southeast Asia. Acid sulfate soils occur mainly in the Bangkok Plain in an area of about 0.8 million hectares, of which 95% is used for lowland rice production. Due to the acidic nature of the acid sulfate soils, rice production on these soils in the Bangkok Plain is often severely limited (Kevie and Yenmanas, 1972).

The major limitations on rice growth in acid sulfate soils are high P-sorption capacity (Attanandana, 1982) resulting in P deficiency and Fe and Al toxicity (Jugsujinda et al., 1978). Since P-sorption mechanisms in acid sulfate soils are greatly influenced by the forms and amounts of Fe and Al compounds, it is probably that soil Eh

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and pH condition, which control iron and aluminum reactions, govern the release and sorption of P in the acid sulfate soils. The P-sorption of soil has been reported to either increase (Haynes and Swift, 1985; Trana et al., 1986) or decrease (Lopez-Hernandez and Burnham, 1974; Smyth and Sanchez, 1980) as pH increase. Khalid et al. (1977) reported that more P was sorbed under reduced condition than under oxidized condition at high level of added P.

Rice is grown under a wide range of oxidized and reduced soil conditions with varied Eh and pH levels. P-sorption characteristics under the different Eh and pH levels in acid sulfate soils of Thailand have not been thoroughly investigated.

The objectives of this research were to investigate P-sorption characteristics of the acid sulfate soils of Thailand under uncontrolled or oxidized and reduced soil conditions, and under different controlled Eh and pH levels of the soils. Relationships between P-sorption parameters and Fe, Mn and Al in these soil conditions are also reported.

Materials and methods

Experiment 1. P-sorption in acid sulfate soils under oxidized and reduced conditions

The surface layer (0–15 cm) of the acid sulfate soils used in this study were collected from the Bangkok Plain of Thailand. Soils were air-dried, sieved (<2 mm), and thoroughly mixed prior to chemical analysis. In this study one para-acid sulfate soil (Typic Tropaquepts), Bangkok (Bk) (pH 4.9), and three actual acid sulfate soils (Sulfic Tropaquepts/Typic Sulfaquepts), Maha-Phot (Ma) (pH 4.5), Rangsit (Rs) (pH 4.3), and Rangsit very acid (Rsa) (pH 3.9) were used. These soils represent sites where rice is produced on the Bangkok Plain. General morphology and chemical characteristics of the soils were described by Kevie and Yenmanas (1972). Selected soil physical and chemical properties are presented in Table 1.

Suspensions of 250 g soil in 1750 mL 0.01 M CaCl₂ were incubated in laboratory microcosms under oxidized and reduced conditions for four weeks at 25 °C (4 replications): The microcosm consisted of a 2-L widemouth flask with rubber stopper. Two platinum electrodes, a salt bridge and a combination glass electrode were permanently inserted through the rubber stopper to measure Eh and pH. The soil solution was kept in suspension by a magnetic stirrer and a stirring bar. N₂ and O₂ gases bubbled continuously through the soil suspensions through the gas inlet and gas outlet at a slow rate of flow to promote reduced and oxidized conditions, respectively. The redox potential and pH of the system were monitored. Prior to the incubation, the soils were amended with 0.2% finely ground rice straw which provided an energy source to promote microbial activity. At the end of the incubation period, the soil suspensions (50 mL) were then transferred to 250 mL polycarbonate centrifuge bottles and P in concentrations ranging from 0 to 500 mg P kg⁻¹ soil as KH₂PO₄ was then added to the soil suspensions. For the reduced condition treatment, the centrifuge bot-

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>Bangkok (Bk)</th>
<th>Maha-Phot (Ma)</th>
<th>Rangsit (Rs)</th>
<th>Rangsit very acid (Rsa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Soil Group</td>
<td>Typic Tropaquept</td>
<td>Sulfic Tropaquept</td>
<td>Sulfic Tropaquept</td>
<td>Sulfic Tropaquept</td>
</tr>
<tr>
<td>Acidity class</td>
<td>Non-acid</td>
<td>Moderately acid</td>
<td>Severely acid</td>
<td>Extremely acid</td>
</tr>
<tr>
<td>pH (1:1 water)</td>
<td>4.9</td>
<td>4.5</td>
<td>4.3</td>
<td>3.9</td>
</tr>
<tr>
<td>Organic matter (%)</td>
<td>1.3</td>
<td>1.9</td>
<td>3.3</td>
<td>4.4</td>
</tr>
<tr>
<td>Available P₅</td>
<td>19.2</td>
<td>3.2</td>
<td>5.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Exchangeable Al (cmol kg⁻¹)</td>
<td>1.1</td>
<td>2.3</td>
<td>2.0</td>
<td>10.1</td>
</tr>
<tr>
<td>Exchangeable acidity (cmol kg⁻¹)</td>
<td>1.2</td>
<td>3.2</td>
<td>2.9</td>
<td>10.5</td>
</tr>
<tr>
<td>CEC (cmol kg⁻¹)</td>
<td>24.9</td>
<td>19.9</td>
<td>20.8</td>
<td>21.8</td>
</tr>
</tbody>
</table>

*aWalkely-Black (Allison, 1965).

*bModified Bray II; soil-extractant = 1:10.

*c1 M KCl.

*dBaCl₂-Trelthanolamine (Peech, 1965).

*eAmmonium saturation-distillation (Chapman, 1965).