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# The links between potassium availability and soil exchangeable calcium, magnesium, and aluminum are mediated by lime in acidic soil

Tianfu Han[1,2] · Andong Cai[1] · Kailou Liu[1,3] · Jing Huang[1] · Boren Wang[1] · Dongchu Li[1] · Muhammad Qaswar[1] · Gu Feng[2] · Huimin Zhang[1]

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## Abstract

**Purpose** The aims of this study were to investigate the links between potassium (K) uptake by crops and soil K, exchangeable calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), and aluminum ($Al^{3+}$) when using lime in acidic soil in southern China.

**Materials and methods** Soil samples of three treatments (chemical NP fertilizers, NPK, and NPK plus straw (NPKS)) were collected from a 26-year field experiment (0–20 cm) and then a rhizobox experiment was conducted with seven lime application rates (0–2.26 g $kg^{-1}$). We investigated the soil exchangeable $K^+$, $Ca^{2+}$, $Mg^{2+}$, and $Al^{3+}$ and non-exchangeable K (NEK) in the rhizosphere soil (RS) and non-rhizosphere soils (NRS), and K uptake by crops.

**Results and discussion** As lime addition rates increased, the average concentration of exchangeable K (EK) in RS under NPK and NPKS treatments decreased to 46.5 mg $kg^{-1}$ and 70.4 mg $kg^{-1}$ for maize and wheat, respectively. In treatments with lime application, the NEK concentration was higher in RS and NRS compared with the no-lime in NP treatment but was lower in RS in treatments with K fertilizer input (NPK and NPKS). The K uptake by crops under lime application significantly ($p < 0.05$) increased by 37.6% to 155.1% compared with the no-lime treatments. Lime application significantly increased soil exchangeable $Ca^{2+}$ (42.9 to 255.7%) and decreased exchangeable $Al^{3+}$ (23.7 to 86.6%). According to structural equation modeling, lime indirectly influenced K uptake by crops through its effects on soil exchangeable $Ca^{2+}$+$Mg^{2+}$ and $Al^{3+}$, EK, and NEK, which accounted for up to 39% (RS) and 46% (NRS) of the variation in the K uptake by crops. Lime directly and negatively affected EK and NEK in NRS but had no direct effects on EK and NEK in RS.

**Conclusions** Our results suggested that lime-induced K uptake by crops was mediated by $K^+$, $Ca^{2+}$, and $Al^{3+}$, and that lime application resulted in higher soil K availability.

**Keywords** Acidic soil · Exchangeable $Ca^{2+}$ · Exchangeable $K^+$ · Lime addition rate · Long-term fertilization · Rhizosphere

Tianfu Han and Andong Cai contributed equally to this work.

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✉ Huimin Zhang
zhanghuimin@caas.cn

[1] National Engineering Laboratory for Improving Quality of Arable Land, Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China

[2] Environment and Food Security, College of Resources and Environmental Sciences and Centre for Resources, China Agricultural University, Beijing 100081, China

[3] National Engineering and Technology Research Center for Red Soil Improvement, Jiangxi Institute of Red Soil, Jiangxi 331717, China

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