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Through which pathways can earthworms increase soil phosphorus availability?

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In the search for a more sustainable form of agriculture, a better recycling of major nutrients is essential. For phosphorus (P), one of the most limiting factors to better recycling is chemical adsorption to reactive soil particles, which seriously restricts P supply to plants in many soils. It has been known for some time that earthworms can temporarily increase soil P availability in their casts. However, the exact pathways behind this effect are unclear, making it difficult to infer under which conditions earthworms may significantly contribute to P recycling. In two greenhouse experiments, we studied the occurrence of earthworm-induced increased P availability (i) across a range of common earthworm species; and (ii) across four soils with different physico-chemical characteristics. In the first experiment we analyzed casts of eight common Dutch earthworm species for P pools and related soil properties. For all species, pH in casts was higher than in the bulk soil (up to 1.6 pH unit). Dissolved Organic Carbon (DOC) concentrations were an order of magnitude higher in the casts, and directly available P (defined as water-soluble ortho-phosphate) up to two orders of magnitude. Although these effects were significant for all earthworm species, significant changes were found between the species that could not be explained by conventional earthworm feeding guilds. In the second experiment, we tested effects of three different earthworm species across four soils differing in texture, metal oxide composition, P availability and pH. We found a significant effect of earthworms on P availability in all soils, but the extent of this effect varied. Using surface complexation modeling we evaluated the relative importance of the various possible mechanisms. We concluded that the effect of pH on P desorption was relatively small. Increased mineralization of organic P did play an important role; as did competitive desorption of DOC to metal oxides. However, our study also showed a new important pathway: a reduction in reactive surface area of soil metal (hydr)oxides during earthworm gut passage. As this decrease was important in iron (hydr)oxide-dominated soils but not in aluminum (hydr)oxide-dominated soils, we suggest that earthworms have the largest potential to affect soil P availability in the former soils.