Geophysical Research Abstracts
Vol. 19, EGU2017-18909, 2017
EGU General Assembly 2017

Earthworms and nutrient availability: the ecosystem engineer as (bio)chemical engineer

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The ability of earthworms to increase plant production has long been recognized. However, the pathways through which they do so, and the magnitude of this effect, have not been conclusively addressed. In two studies we address these issues for nitrogen (N) and phosphorus (P) availability to plants. In the first study, a meta-analysis, we concluded that earthworm presence increases crop yield on average with 26% and aboveground biomass with 24%. The positive effects of earthworms increase when more residue is returned to the soil, but disappear when soil N availability is high. This suggests that earthworms stimulate plant growth predominantly through N mineralization from soil organic matter or crop residue. In a second study, we tested the effect of earthworms on plant P uptake from inorganic sources. In a greenhouse experiment on a soil with low P availability we showed that presence of the anecic earthworm Lumbricus terrestris resulted in increased aboveground biomass (from 164 to 188 g dry matter m-2) and P uptake (from 0.21 to 0.27 g m-2). Concentrations of total dissolved P and dissolved inorganic P in water extractions of earthworm casts were 7-9 times higher than in those of bulk soil. Using advanced surface complexation modelling, we showed that these effects were primarily related to desorption of inorganic P due to competition with organic carbon for binding sites. We conclude that earthworms can alter nutrient cycling and increase N and P uptake by plants through a combination of biochemical and chemical pathways. Earthworms are most likely to stimulate N uptake in organic farming systems and tropical subsistence farming, which largely rely on nutrient mineralization. Additional benefits of earthworms might be expected in conventional farming systems with low levels of available P.