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Conference Abstract

Dueling Plant Phosphorus Acquisition Strategies Over a Geochemical Gradient: A Biogeochemistry Experiment Approach

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Abstract

Plants are likely to be phosphorus (P)-limited because of low availability of P to roots or mycorrhizae due to slow diffusion and high sorption in soils. Phosphorus sub-cycles (inorganic versus organic) also tend to vary predictably over gradients (Fig. 1A,B). Plant responses to mycorrhizal fungi also vary by plant species and grassland type (Reinhart et al. 2017). Mycorrhizae can scavenge nutrients (i.e. orthophosphate, organic-P); however, if they cannot solubilize calcium bound P, then geochemical gradients may constrain plant-mycorrhizal interactions (Fig. 1C).

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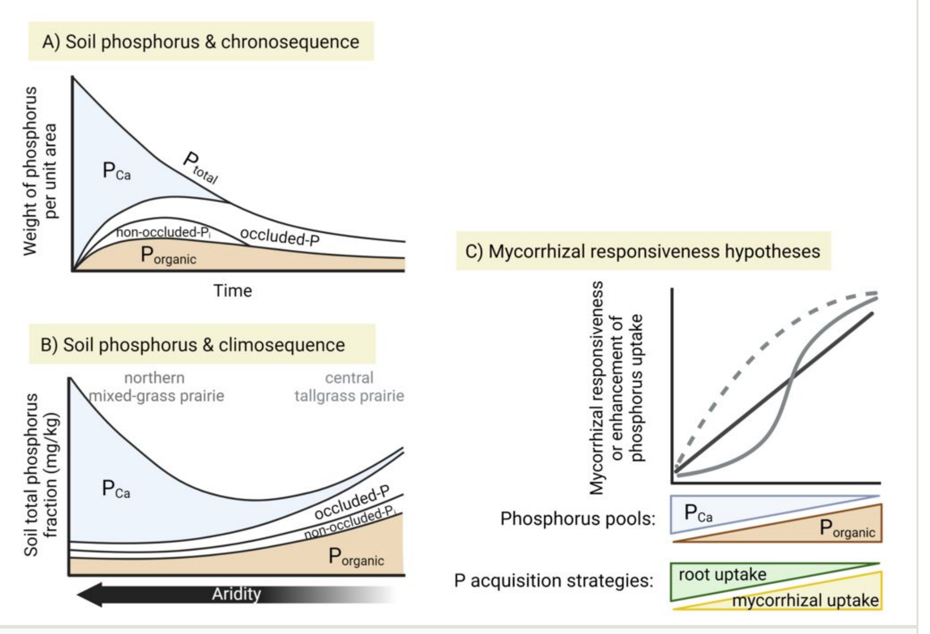

Figure 1. doi

Figure 1 Phosphorus (P) fractions are known to vary along chronosequences (A) and climosequences (B) and may drive plant growth responses to mycorrhizae (C). Chronosequence panel was redrawn from Walker and Syers (1976), and climosequence panel was based on Feng et al. (2016) and Ippolito et al. (2010). Mycorrhizal responsiveness hypothesis (linear) followed Albornoz et al. (2020) and alternatives (nonlinear). P_{Ca}= calcium phosphate minerals, $P_{organic}$= organic P, occluded-P= P stabilized in secondary minerals, and non-occluded-P_i= bioavailable (inorganic) phosphates.

Calcareous soils are found in >30% of soils and are common in arid, semiarid, and semi-humid systems (e.g. grasslands, shrublands). We used geochemical and biogeochemical experiments to test hypotheses on P limitation and acquisition (Lajtha and Schlesinger 1988). Hypothesis: an increase in soil calcium carbonate ($CaCO_3$) will 1) reduce soil P bioavailability (geochemical exp.), 2) reduce plant biomass and phosphorus uptake (biogeochemical exp.), and 3) shift P acquisition strategies (i.e. root mining, mycorrhizal scavenging) (biogeochemical exp., Fig. 1C).

Experiments had a replacement series ($CaCO_3$ to silica sand) geochemical treatment ($CaCO_3$ additions: 0, 0.02, 0.10, and 0.30 [g × 100 g^{-1}]) to simulate soil properties over natural grassland gradients. The biogeochemistry experiment was a completely randomized design with the geochemical and mycorrhizal fungi treatments (+, -) (4 × 2 factorial), 8 plant species, and 8 replications. Geochemical exp.'s response variables were soil extractable nutrients and pH. Biogeochemistry exp.'s response variables were nutrient uptake and plant performance.

The geochemical experiment confirmed that increasing $CaCO_3$ increased pH_{water} of subsurface soil (7.6 to 8.5), reduced the intensity of available P (assessed by anion exchange membranes) in treated soils by as much as 57%, and had no obvious effect on accessible P (Olsen-P). In other words, metaphorical cups of P (with straws) had similar amounts of accessible P per cup; however, additions of $CaCO_3$ effectively reduced the straws' diameter and limited (re-)supply of available P.

On average, large additions of $CaCO_3$ reduced plant biomass by 20% and plant uptake of P by 15% for the biogeochemistry experiment. On average, mycorrhizal fungi increased plant biomass by 6%. Rarely did mycorrhizal fungi and geochemical treatments interact and affect plant biomass. When they did interact, mycorrhizae benefited plants in pots with greater levels of P intensity (i.e. no or little added $CaCO_3$) thereby suggesting mycorrhizae may not help to solubilize calcium bound P.

These findings confirm $CaCO_3$ in subsoils reduced the intensity of bioavailable P, which consequently decreased plant biomass and P uptake. However, we cannot rule out that $CaCO_3$ additions may have additionally impacted plants response due to changes in micronutrient solubility (i.e. zinc), etc. (Lajtha and Schlesinger 1988). While plants tended to benefit from mycorrhizae, we found no evidence to support a prediction of the nutritional mutualisms hypothesis—that benefits are greatest under P-limitation. On the contrary, our data suggest that plants will rely more on root mining P acquisition strategies than mycorrhizal scavenging (Albornoz et al. 2020) where the inorganic-P sub-cycle dominates and P solubility is limited due to calcium-phosphate formation (Fig. 1C).

Keywords

mycorrhizal dependency, plant-mycorrhizal interactions

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Conflicts of interest

The authors have declared that no competing interests exist.

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