Evolutionary advances in land plants and fungal symbioses: Effects on global biogeochemical cycles

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The evolution of land plants with symbiotic soil fungi set in chain a sequence of events that greened the Earth's continents with ecosystems of increasing biomass and complexity. We hypothesise: (1) As plants evolved in stature, biomass, and rooting depth, their mycorrhizal fungal partnerships received increasing amounts of plant photosynthate. This enabled them to become progressively more potent partners in weathering of the growth-limiting element P from calcium phosphates. (2) Increasingly targeted and intensive plant-driven fungal weathering to release P from apatite has transformed biogeochemical cycles of C, Ca and P to effect biosphere-geosphere-ocean-atmosphere interactions and feedbacks over the past 400 Ma.

These hypotheses are evaluated in the light of experimental evidence from field and laboratory studies, together with analysis of palaeosols developed under some of the Earth's earliest forest ecosystems, over 350 Ma ago. We report increasing intensification of Ca release from silicate and carbonate minerals in relation to evolutionary advancement of gymnosperm and angiosperm tree taxa, and demonstrate that rates of photosynthate allocation to mycorrhizal fungi controls their weathering rates. Changes in atmospheric CO_2 concentrations through the Phanerozoic are shown to provide critical controls that regulate rates of plant-driven fungal weathering via photosynthate fluxes, which can feedback on the land-to-ocean Ca fluxes that control the geochemical C cycle over millions of years.

Our findings reveal plant-mycorrhizal evolutionary advances act as potent cogs in the transformations of the biosphere, geosphere, oceans and atmosphere by terrestrial ecosystems, through their impacts on the flows of nutrients, carbon and energy over hundreds of millions of years.