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33P-Labeling techniques for imaging experiments to mechanistic phosphorus cycle studies

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Phosphorus (P) is a major nutrient for plants, but a finite non-renewable resource of modern agriculture. What is more, the P use efficiency of fertilizer is usually low, because of rapid immobilization of available P by sorption to soil minerals. To quantify P use efficiency and potential remobilization kinetics, a method is required, which at best quantifies and images P in soil plant systems at high spatiotemporal resolution.

Here, we used 33P labeling for bioimaging in order to elucidate (I) the role of artificial and natural created biopores for plant P uptake, (II) solubilization possibilities from (radioactively labeled) apatite as well as (III) the use of (fed with 33P-labeled nutrient solution) harvested microalgae biomass with capability to accumulate large P quantities and delayed release as alternative fertilizers closing the cycle from waste back to agricultural topsoils.

For these goals, (multiple step) labeling techniques based on isotope exchange were developed and optimized towards high yields. Alternatively, labeled hydroxyapatite was made by means of wet-chemical total syntheses under different reaction conditions with subsequent analytical characterization of the sintered products.

Comprehensive rhizotrone experiments using different subsoil types and water scenarios with spring wheat as model plant showed the following results:

• The presence of macropores do not improve plant growth and subsoil nutrient uptake, but tend to increase translocation of 33P into above- and belowground plant biomass after re-allocation of topsoil-P for subsoil root growth.
• Plants are able, to actively solubilize P from apatite, however without interference of the surrounding substrates. The 33P incorporation increases with the degree of water access to subsoil roots. Sand as extreme nutrition deficit variant shows the 33P enrichment predominantly in the ears, independent from watering system. In contrast, in more soil 33P is translocated across the whole plant.
• Algae show analogous excellent plant growth and development status like reference mineral fertilizer with some intended, delayed P-availability. For more than ten weeks 33P activity is more or less uniformly translocated across above ground plant parts. The ideal nutrition status leads to late ear formation.
Overall, our data thus show that repeated radioactive imaging with high resolution pictures allows for assessing the growth and development of the root systems during P uptake, as well as for quantifying phosphorus translocation into the above ground plant parts.