C-dots as non-toxic, non-destructive novel tracers to measure biochemical cycles in the soil-plant-atmosphere continuum

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Tracers provide a way to determine, follow and quantify biochemical cycles and energy fluxes within the soil-plant-atmosphere continuum (SPAC). Thereby, different tracers, such as dyes, carbonyl sulfite or stable isotopes are employed. One major disadvantage of many tracers is, that very often, plants have to be destructively harvested to analyze the tracer concentration, making it difficult to measure continuous fluxes. Additionally, for stable isotope studies, fractionation or exchange effects can make interpretation and quantification of biogeochemical fluxes difficult. Novel tracers that are already frequently used in animal systems, are fluorescent C-dots. These nanoparticles (5-50 nm diameter) provide a non-destructive imaging option using “in vivo imaging systems” (IVIS). We examined a first approach to apply and measure C-dots as possible tracers in tree saplings of three species (Picea glauca, Pinus strobus, Tsuga canadensis). Roots were excavated from soils and exposed to 20 µmol/l liquid silica-based nanoparticles (diameter of 5.1 nm) labeled with a near-infrared fluorophore, cyanine 5.5 (excitation maximum 646 nm, emission maximum 662 nm). Subsequent continuous IVIS imaging showed real-time uptake and transport of the C-dots by the trees. Respective fluorescence intensity revealed the concentration of C-dots in each of the tissues at measured time steps. Subsequent cross-sectioning of roots, stems and leaves elucidated the internal transport pathway of the C-dots inside the saplings' tissues. Finally, measurements of stomatal conductance, photosynthesis, transpiration rate, stem hydraulic conductivity and pre-dawn leaf water potentials in comparison to control saplings revealed no phytotoxic effect by the C-dots on plant functioning. In conclusion, C-dots provide a non-toxic new technique for measuring biochemical cycles within the SPAC. Future applications include high resolution tracing of water flow cycles and turnover times within the SPAC, compound specific analyses of root exudation or determining mechanisms of pest influences on plant metabolism.