Biofunctional Microgel-Based Fertilizers for Controlled Foliar Delivery of Nutrients to Plants

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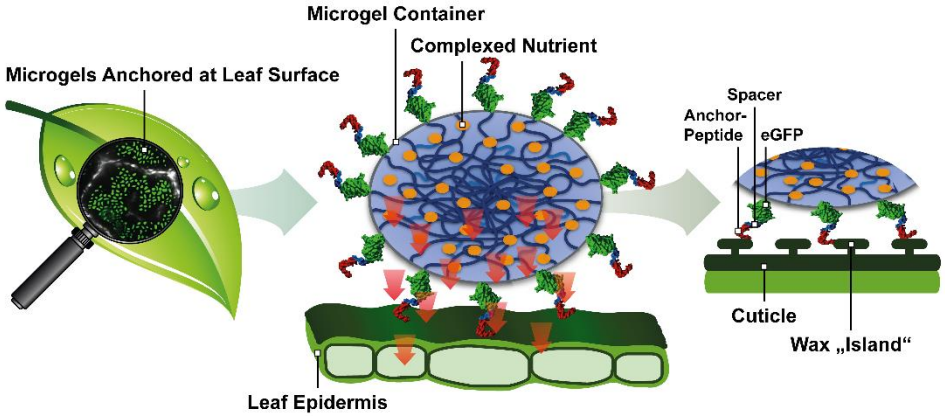
Development of a microgel-based foliar fertilizer with the aid of anchor peptides as adhesion promoter for increased rainfastness

Foliar application of micronutrients (e.g. iron(III) ions) onto plants over an extended time is challenging and often not possible due to insufficient rainfastness. Smart delivery systems which enable micronutrient release over several weeks would offer innovative and sustainable options to improve plant health and food production. Herein, we report a novel foliar fertilizer delivery system based on functional pH-responsive biohybrid microgels that have orthogonal functionality as carriers of micronutrients and employ peptides (termed anchor peptides) as foliar adhesion promoters. We have designed a novel delivery system for plant micronutrients based on anchor-peptide-decorated poly(allylamine) microgels. The post-modification with 2,3-dihydroxybenzoic acid by *N*-hydroxysuccinimid-coupling was used to decorate the interior of the microgels and anchor-peptide fusion proteins were used to decorate the surface of microgels by means of thiol-ene click chemistry. Our experimental data indicate that microgels can be loaded with tunable amounts of iron(III) ions and show strong binding to leaf surfaces; the anchor peptides bind to hydrophobic surfaces and the waxy “islands” of plant leaves. The application of iron(III) loaded microgels onto iron-deficient cucumber plants – as a “proof-of-concept” – showed significant “re-greening” and increase of the chlorophyll content in leaves confirming an efficient delivery and bioavailability of metal ions. The biocompatible and non-phytotoxic nature of poly(allylamine) microgels enables their general application as delivery systems for plants. Our system requires no auxiliaries and is loadable, storable, and applicable from aqueous dispersion.



Scheme 1 Concept of biofunctional microgel-based fertilizers for specific attachment to leaf surfaces and controlled foliar delivery of nutrients to plants.

The industrial application of microgels as fertilizer systems is envisioned because of the low estimated production costs (cost of microgels 8–10 EUR per kg on laboratory scale plus cost of anchor-peptides less than 1 EUR per kg microgel), a high loading capacity (30–50% nutrient per polymer dry weight), a straightforward and simple handling of the microgels, and its high flexibility in terms of encapsulated nutrient and tunable adhesion to various plant species. We believe that the microgel container concept can be extended to different types of active molecules (e.g. priming compounds, fungicides, insecticides) able to improve plant viability and productivity. The modification of the microgel interior can ensure high loading and programmed release with high efficiency to match application demands and reduce environmental pollution.