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*Perspective*

# Interface of nanoparticles cross barriers in plants

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## ABOUT THE STUDY

Agriculture must adapt to increased exposure to the smallest plastic particles as it strives to feed an increasing population. To dive more deeply into how plants gather nanoplastics, we arranged clear cut block copolymer nanoparticles by watery scattering polymerization. Using confocal microscopy, fluorophores were incorporated into Arabidopsis protoplasts through hydrazone formation and root uptake. Here, we demonstrate that the ratio of nanoparticle size to uptake is inverse. Negatively charged nanoparticles slowly accumulate and gradually appear in the xylem of intact roots, whereas positively charged particles accumulate around the surface of roots and are not taken up by roots or protoplasts. Although xylem loading is lower than that of negative nanoparticles, neutral nanoparticles penetrate intact cells at the surfaces of plant roots and into protoplasts quickly. Our findings demonstrate that plants are susceptible to nanoplastics in soil and water, despite the protection afforded by rigid cell walls. These behaviors are distinct from those of animal cells.

The creation of synthetic polymeric materials, particularly plastics, was one of the most significant scientific advancements of the 20th century. There is growing concern about the contamination of marine and terrestrial environments by primary (intentionally added, such as microcapsules for controlled release of agrochemicals) or secondary (breakdown products of larger plastics) micro- and nano-sized plastic particles, with a Food and Agriculture Organization report highlighting the growing danger of plastics in soils. Applications that use plastics have increased exponentially. Hard particles, mostly metal-based nanoparticles with a few involving structured carbon, chemically crosslinked polymers like polystyrene and polyethylene beads, and so-called superabsorbent polymers used for soil remediation, have been the focus of studies on the effects of nanoparticles on plants. However, little is known about whether soft, polymer-based nanoparticles will be absorbed by plants or if they will accumulate during their transit through plants. It is essential to determine the physicochemical properties that govern or limit uptake of these materials by plants and to assess whether they might be taken up by plants in light of the increasing load on agricultural environments caused by the breakdown products of waste plastics and the development of soft nano- and microplastics as precision delivery vehicles for agrochemicals. Model systems are needed to track and evaluate the effects of soft polymer nanoparticles, whose flexile structures and environmental responsiveness may enable them to be taken up and distributed in plants more effectively than their stiffer, more crystalline counterparts, given the current transition toward bio-sourced and biodegradable polymers for agricultural mulches and delivery systems as well as plastic waste reaching agricultural soils.

To produce polymer nanoparticles that can serve as agrochemical delivery vectors, conventional polymer self-assembly methods (thin-film rehydration, solvent-switch) have typically been utilized. Particle size cannot be controlled for comparable polymer formulations thanks to these methods' limited scalability and reproducibility. Self-assembly methods that enable the synthesis of nanoparticle sizes that can be controlled are needed to generate model systems for testing the uptake of soft nanoparticles by plants.

Utilizing block copolymers, Polymerization-Induced Self-Assembly (PISA) permits the controlled production of flexible plastic nanoparticles. The ratio of hydrophilic to hydrophobic blocks, for instance, can be changed to alter the size of the nanoparticles. Additionally, we are able to impart a variety of surface functionalities due to his PISA's compatibility with a number of polymerization methods, including Ring-Opening Metathesis Polymerization (ROMP), atom transfer radical polymerization, and Reversible Addition-Fragmentation Chain Transfer (RAFT).

The incorporation of various soft plastic polymer nanoparticles into Arabidopsis roots is examined in this study. With nanoparticles of varying surface functionality (cationic, neutral, and anionic) and small size, incubate both intact roots and isolated cell wall-depleted root protoplasts. RAFT-PISA was used to make nanoparticles, and chemical conjugation of fluorophores made it possible to use confocal microscopy to see inside plant cells and tissues. screening the effects of systematically altering key physicochemical properties of soft polymer nanoparticles, such as size, surface charge, shape, stiffness, and hydrophobicity, as part of a secure design strategy for applications like precision agriculture, demonstrating how PISA could be an eco-friendly alternative to today's "plastic culture."

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