Engineered nanomaterials have the potential to revolutionize agrochemical delivery, efficacy, and use efficiency, and to improve the sustainability of agriculture. We assessed the importance of nanomaterial properties, including charge, size, composition, and coating hydrophobicity to promote efficient uptake and translocation of engineered nanomaterials in plants after foliar and root exposures. Spatially resolved synchrotron X-ray imaging tools demonstrated that coating hydrophobicity controls both route and extent of nanoparticle uptake across the plant leaf cuticle for foliar applied nanomaterials, and the ease of transport through leaf mesophyll into the plant vasculature. NP size up to 50nm did not influence NP uptake through the cuticle, but size did influence their leaf-to-root transport and root exudation. Selected NP coatings can also target NPs to specific leaf features like stomata guard cells. Finally, we have developed a temperature-responsive star polymer that can release active ingredients in vivo under heat stress. Overall, the body of evidence indicates great potential for manipulating nanomaterial properties for beneficial applications in agriculture and for increasing agrochemical utilization efficiency and sustainability of food production.

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