Food security is threatened by increasing consumption and decreasing crop yields amid population growth and climate change. To mitigate these threats, genetic engineering of plants can be employed to create crops that have higher yields and nutritional value, and are resistant to biotic and abiotic stresses such as diseases and drought. Despite recent progress in the genome editing field, most plant species remain difficult to genetically engineer due to the rigid plant cell wall with a strict size exclusion limit that challenges efficient biomolecule transport into plant cells. The current workhorse method of DNA delivery to plants limits the range of transformable plant species and results in uncontrolled transgene integration, hence eliciting regulatory review of edited plants as genetically modified organisms (GMOs), which is lengthy and costly. Therefore, the development of a delivery tool that is non-pathogenic, non-integrating, and species-independent will greatly advance agricultural biotechnology. In this seminar, I present the development of a nanomaterial platform that can efficiently deliver genes into both model and agriculturally-relevant crop plants, without mechanical aid, in a non-toxic and non-integrating manner; a combination of features that is not attainable with existing plant transformation approaches. I discuss how single-walled carbon nanotubes can be chemically modified to both load and deliver DNA to plant cells for expression of functional proteins in various plant species including tobacco, arugula, wheat, and cotton. Efficient delivery and transient expression of plasmid DNA is achieved in mature plants, notably without transgene integration into the plant genome, a feature that could assuage regulatory oversight of the transformed plant as a GMO. This seminar also elucidates the underlying principles of nanoparticle transport across the plant cell wall. I discuss the effect of nanoparticle physiochemical properties (size, shape, aspect ratio and stiffness) on plant cell uptake, which we systematically investigate by leveraging the facile programmability of DNA nanostructures. Importantly, the identification of optimal nanomaterial parameters for maximum plant cell uptake enables rational design of nanomaterials. These developments demonstrate the unique abilities of nanomaterials to address the main bottlenecks of plant genetic engineering for a sustainable future with food security.