Engineered nanomaterials defend against biotic and abiotic stresses in crops

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Engineered nanomaterials have shown great potential to improve crop resistance, crop yield and quality. Under laboratory conditions, nano-scale macroelements (e.g., nanoscale hydroxyapatite), microelements (e.g., copper phosphate nanosheets, copper oxide nanoparticle-embedded hydrogels), beneficial elements (e.g., Se nanoparticles), and carbon-based nanomaterials (e.g., carbon nitride, gC3N4) were synthesized. The synthesized nanomaterials were applied on leaf surfaces or root rhizosphere to mimic the application of agrochemicals in the fields. The results of Cu2+ ion release showed that at the equivalent Cu molar concentration, more Cu2+ ions were released from copper phosphate nanosheets than from copper oxide nanosheets or commercial copper oxide nanoparticle, and the release pattern was affected by organic acids, amino acids and sugars in phloem saps. In terms of alleviating biotic stresses, the pot experiment results showed that Fusarium infection reduced the crop biomass by 62%. However, the disease incidence decreased by 31% on average after foliar-spraying copper phosphate nanosheet, thus increasing the biomass of crops. It is worth pointing out that in comparison with nanoparticles, nanosheets significantly increased copper content in the aboveground part, which was further confirmed by SEM-EDS of Cu distribution on leaf surfaces. At biochemical and molecular levels, nanomaterials could significantly alleviate the plant antioxidant defense systems induced by Fusarium. Compared with commercially copper oxide nanoparticles, copper phosphate nanosheets rapidly up-regulated defense-associated genes at the early stage of crop infection. Phytohormones and fatty acids play an important role in plant resistance to biotic stress. In terms of alleviating abiotic stress, gC3N4 significantly reduced heavy metal-induced abiotic stress to rice by regulating the composition of endophytic microbial community, tyrosine metabolism, pyrimidine and purine biosynthesis, phenylpropanoid biosynthesis pathways. Taken together, nanoscale agrochemicals exhibit huge potentials to improve crop stress resistance, and further mechanistic explanation can provide a solid foundation for promoting the large-scale application of nanoscale agrochemicals in sustainable agriculture.