Title:	Graphene oxide-based composites for stimuli-responsive agrochemicals delivery and to augment plant functions through nanobionics approach
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Abstract:	The productivity of modern agriculture depends on the agrochemicals, which enhance production, protection, and preservation. But these micron-scale agrochemicals formulations lack application efficiencies, therefore, novel eco-friendly formulations are pursued to prevent the major biological disasters and ensuring food security. In recent years, the development of nanomaterials-based formulations has shown significant improvement in the performance of fertilizers, pesticides, and preservatives. Hence, in each of these aspects, we identified the present gap and tried to address by taking advantage of the intrinsic property of graphene oxide (GO). In the crop protection formulations, more than 90 % of pesticide goes non-targeted. Hence, we tested the ability of the GO to overcome washing loss, which accounts for a huge share of loss. Here, GO was decorated with copper selenide (Cu 2-x Se) nanocrystals (GO-Cu 2-x Se), so that in addition to the GO's sticking nature the composite will have programmed pesticide degradation to present sustainable agricultural ecology. The GO-Cu 2-x Se composite was loaded with the pesticide and found to show enhanced drift resistance. This enhanced binding resulted in efficient pest (Pieris rapae larvae) control. The material also added the advantage of stimuli- responsive pesticide release. After testing the potential of GO for pesticide application, the application of as-synthesized material (GO-Cu 2-x Se) was also extended for the antifungal pesticide application. As copper- based salts are the best recommended field solution for the agricultural disease control until now. Here, the material in combination with the commercial fungicide was tested for combined fungus control efficiency. The material in combination with amphiphilic polymers having different charge was tested, to screen the best combination of material and charge for the enhanced adhesion to the leaf surface. The formulation also controlled the leaching, which often leads to groundwater pollution. Finally, the fungicide loaded composite found to show enhanced antifungal activity against Colletotrichum capsici in a stimuli-responsive fashion. Following the pesticide and fungicide application with the support of GO, GO-based formulation was developed for the preservative delivery. Post-harvest agricultural loss accounts for 20-50 % annually and the reports about preservatives toxicity are also increasing. Hence, to develop a safe preservative application, GO was conjugated with the preservative through acid-sensitive hydrazone bond via simple 2 step activation steps. Here, we found that preservative release from GO due to cleavage of the acid-labile hydrazone bond in the presence of acid synthesized in the over ripen fruit. In comparison to free preservative, the composite shows less toxicity. Finally, GO-preservative composite based robust wrapper was prepared through vacuum-infiltration for the fruit storage. Among various interesting properties of GO, optical properties are important for plant applications. Hence, we studied the positive and negative aspects of the GO in the plant by taking chloroplast as the single-cell plant body. The interaction of GO without and with amine conjugation (AGO) having opposite charge was documented using biolayer interferometry coupled with confocal imaging. The ex vivo chloroplast activity with GO and AGO was tested and found that the GO treatment shows 1.3 times more activity than control; whereas AGO shows a negative effect. Finally, in vivo toxicity was evaluated in the spinach plants.
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