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Iron Oxide based Nanocomposites for sustainable fertilization

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In 2050 the world population is estimated to reach 10 billion people, and a simultaneous increase in global food demand is predicted. However, the current methods of cultivation are known not be efficient enough to address this issue. In this work an innovative smart hybrid nanocomposite based on iron oxide is described as an alternative nanoscale fertilizer. Iron is an essential micronutrient for plant growth and development, its deficiency disrupts major metabolic and cellular activities such as respiration, DNA synthesis, and chlorophyll synthesis. Iron also activates various metabolic pathways and is vital to numerous enzymes. Though it is widely distributed in soil, plants do not readily absorb it because Fe forms insoluble Fe complexes under alkaline conditions. Currently, used Fe-based fertilizers are expensive, and cause Fe to leach out of the soil with water, thereby diminishing their efficacy. The advantages of alternative nanosized Fe fertilizers include their physical and chemical characteristics, such as the high surface area to volume ratio that permits a more efficient absorption by plants roots and leaves. Moreover, the biopolymeric shell guarantees also a controlled-release of iron oxide nanofertilizers, coordinated with the nutritional needs of the crops. This improves the nutrients accumulation in the plant, filling in the gap of nutrient deficiency and lowering environmental risks due to leaching. For these reasons we have optimized hybrid nanocomposites based on Fe_2O_3 nanoparticles (NPs) loaded inside a biopolymeric shell, made of chitosan. The Fe_2O_3 nanoparticles are stabilized in water with Citrate Tribase Dihydrate (called Fe_2O_3@CTD). The stabilization method of Fe_2O_3 nanopowder was developed in water. We choose citrate as stabilizer, because it guarantees at the same time biocompatibility and biodegradability together to proper functionalization of Fe_2O_3 NPs surface. The main process parameters were optimized, i.e. concentration of each component and their ratio in the mixing solution, time and temperature of ultrasonic bath treatment. The goodness of the obtained samples was verified in terms of size, stability, and amount of iron dispersed in solution. In particular, the morphological investigation was performed by Scanning Electron microscopy (SEM), the stability and size investigation by Dynamic Light Scattering (DLS) and the quantitative analysis of iron content by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). The synthesis of hybrid nanocomposite was carried out by entrapping Fe_2O_3@CTD NPs with Chitosan by ionotropic gelation, and its characterization in terms of morphology, size, stability, molecular structure and amount of iron was also performed respectively by SEM, DLS, FTIR and ICP-MS. This study was performed in the framework of PNRR Samothrace Project.