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Next-Generation Fertilizers: A TiO_2−Chitosan Composite Superabsorbent as a Sustained Release N-Fertilizer

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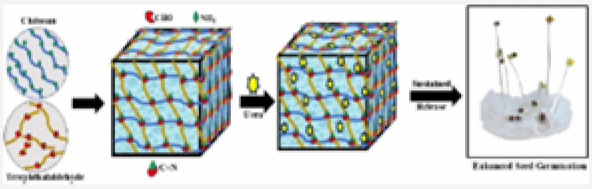

ABSTRACT: This work aims to develop a sustained-release fertilizer by synthesizing a TiO_2−chitosan composite superabsorbent. For this purpose, chitosan was modified with TiO_2 nanoparticles, and terephthalaldehyde was used as a cross-linker. The reaction follows the Schiff base condensation mechanism. Confirmatory characterization of the synthesized material was done using Fourier transform infrared spectroscopy, X-ray diffraction, scanning electron microscopy-energy dispersive X-ray analysis, and X-ray photoelectron spectroscopy. Thermal gravimetric analysis-differential scanning calorimetry was performed to study the thermal behavior of the synthesized material. Rheology was performed for the mechanical studies. The superabsorbent showed excellent swelling behavior. The swelling was studied in different environments; a swelling percentage of 706.6% was observed at room temperature, categorizing the synthesized hydrogel as a superabsorbent. The urea loading at different pHs was also investigated, and a loading capacity of 90% was observed at an acidic pH. Finally, the release of fertilizer from the loaded hydrogel in different media was studied using UV−visible spectrophotometry. Various mathematical models were applied, and the results were fitted to the Korsmeyer−Peppas model. At pH 4, the highest correlation coefficient of 0.89 and an n-value of 0.27 were obtained, showing that the release corresponds to Fickian diffusion. Further, to compare the urea-loaded hydrogel with pure urea, a real-time experiment on the germination of *Brassica oleracea* var. viridis (Kashmiri saag) seeds was performed and a germination index of 274.69% was observed in the case of urea-loaded hydrogel. According to the results, the synthesized superabsorbent showed excellent controlled release in acidic medium and could be employed in soil for agricultural purposes.

■ INTRODUCTION

Nitrogen (N) is an essential component of plant nutrition that significantly impacts crop productivity. However, the percentage of N-based fertilizer that gets utilized is only 30−50%.[1] Inefficient nitrogen absorption raises input costs for farmers and causes numerous environmental issues. Improving nitrogen efficiency, reducing farmers' input costs, and minimizing the environmental impact of N-losses while retaining crop yields are all extremely challenging tasks. These drawbacks can be addressed by introducing slow-release fertilizers (SRFs), which minimize fertilizer loss while releasing fertilizers to plants gradually and at an established pace that fits the plant's nutritional needs.[2] Therefore, the development of water-saving and N-fertilizer-efficient technologies has become imperative for ensuring the economical and ecologically sustainable production of crops.

The ability of sandy soils to hold water and retain nutrients can be enhanced by combining superabsorbents and SRFs.[3] Recent research has shown promising findings that a superabsorbent may regulate fertilizer and water for crop growth, apart from enhancing soil nutrient retention and irrigation efficiency.[4,5] A superabsorbent is a cross-linked three-dimensional hydrogel that can absorb liquids from tens to thousands of times its weight. Under specific pressure, the absorbed liquids are also capable of being retained in the superabsorbent.[6,7] These specific benefits make superabsorbent

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