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ECOFRIENDLY HYDROGELS – THE NEW FRONTIER IN SUSTAINABLE AGRICULTURE

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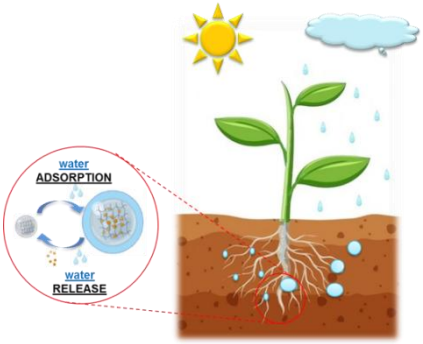
Abstract

Modern agricultural practices supporting production growth are heavily relying on chemical synthesized fertilizers, herbicides, pesticides, etc. at the cost of nutrient leaching, groundwater contamination, and the accumulation of toxic wastes. Abiotic stressors, represented by temperature variations, water scarcity and salinity, etc. are among the main factors affecting agricultural productivity. A variety of cost-effective technologies have been developed to combat hydrological drought. Biotic stressors include insects and pests, pathogens (fungi, bacteria, viruses, and nematodes), and weeds, that also involves synthetic organic compounds, increasing resistance and poisoning agricultural fields and workers. To elude the negative effects of chemicals utilization and provide an effective alternative for sustainable agriculture, hydrogels appear to be revolutionary solution. These polymer networks capable to absorb large amount of water, swell and gradually deswell, allow the controlled diffusion of properly dosed water solutions of bioactive agents. Superabsorbent hydrogels, based on biocompatible and biodegradable polymers, obtained by eco-friendly techniques, are the subject of this presentation. Furthermore, encapsulation of specific soil bacteria, with complementary biological functions, within the hydrogel polymer networks, can be performed. Beyond water supply, these systems synergistic combine nutrient mobilization, phytohormone production, pathogen inhibition, disease suppression, and induction of plant systemic resistance.

Hydrogels in sustainable agriculture

Hydrogels, 3D polymer cross-linked networks, can adsorb large amount of water, from hundred to thousand times in their weight, and further release it to 95%. In agriculture, hydrogels can activate as water reservoirs, if spread around the root mass zones of the plant, increasing soil permeability and improving germination rates. During rain hydrogels can swell and release the water during drought times (graphical abstract). Moreover, the hydrogels may be previously charged with appropriate amount of fertilizers and further gradually release the optimum NPK ratio to specific plants. Based on the sources of the raw materials used as a polymer matrix, hydrogels are classified as synthetic, natural, and synthetic-natural polymer-based. In sustainable agriculture, polymers should be biocompatible and biodegradable, such as polysaccharides. In order to enhance mechanical performances, polymer matrix can be reinforced with natural micro/nanofiller as micro/nano composites.

An important aspect consists in the method used to obtain the cross-linked 3D structure. Cross-linking methods include chemical and physical bonding. Chemical cross-linking involves a cross-linker and formation of covalent bonds with the polymer, leading to stronger interactions within the hydrogel network inducing enhanced mechanical strength and stability. Physical cross-linking consists of multiple non-covalent interactions, such as hydrogen bonding, ionic interactions, van der Waals forces, etc. providing flexibility and responsiveness in the hydrogel structure. The selections of polymer matrix and crosslinking strategy as well as the appropriate fertilizers incorporation into the hydrogel matrix, represent the key factors that determine the effectiveness of hydrogels in the sustainable agriculture.



Conclusions and future perspectives

Hydrogels as bio-based materials with unique physicochemical properties, appear to be modern solutions to old challenges in agriculture. The applications include water solutions release, multiple cycle usage, stimulus responsiveness, and biodegradability. Moreover, the global market for hydrogels forecast a constant increasing, which open up opportunities for investment and innovation in sectors like agronomy. Anyway, further research regarding hydrogel applications in agriculture should prioritize substantiation under real field conditions. This supposes their structure-properties tuning in long-term environmental usage, assessing the effectiveness of controlled-release bioactive systems in heterogeneous soils, ensuring their reliability in specific and/or fluctuating climates, and their specific biological interferences. Hence, more effective strategies can be developed for enhancing and boosting soil health conditions, along with crop productivity, while minimizing environmental impacts and associated risks, encouraging more sustainable and efficient use of resources for the benefit of both farmers and the environment.

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