Improving Soil with Biopolymer Hydrogel: Better Soil Quality and Water Retention

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ABSTRACT

Water scarcity and poor soil quality remain major barriers to agriculture in arid regions such as Oman. This work introduces biodegradable hydrogel composites developed from sodium alginate extracted from brown seaweed, enhanced with Boswellia sacra (frankincense) extract and palm-derived biochar. Their performance was benchmarked against a Russian acrylamide–acrylate copolymer and a Saudi potassium polyacrylate hydrogel. Hydrogel–soil systems were evaluated through soil–water retention modeling (RETC), drying–rewetting cycles, shrinkage and crack analysis, and pH/EC monitoring. Thermogravimetric Analysis (TGA) was also conducted to assess thermal stability and residue formation. The results show that the frankincense hydrogel (F) improved soil water retention, reduced shrinkage, and maintained stable pH. The biochar composite (F+B) provided the greatest structural stability and left the highest char residue in TGA, confirming its reinforcing and carbon-preserving effects. In contrast, synthetic hydrogels absorbed water rapidly but caused surface cracking, increased soil salinity, and underwent almost complete thermal decomposition, offering no long-term residue. These findings demonstrate the potential of locally sourced natural hydrogels as sustainable soil conditioners for desert agriculture. By combining biopolymer design, soil physics, and thermal characterization, this study highlights a viable alternative to synthetic polymers, supporting climate-resilient water management and soil restoration in arid environments.

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