

Hydrophilic Microporous Matrix Hosting a Symbiotic Microbial Consortium for Crop Resilience Enhancement

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Abstract

This work introduces a novel hydrophilic microporous matrix, synthesized via High Internal Phase Emulsion (HIPE) polymerization, uniquely engineered to host a living symbiotic microbial consortium of endophytes and PGPR. Unlike conventional polymeric HIPE materials, which are typically inert, this matrix is specifically designed to preserve microbial viability, enable colonization, and support direct plant–microbe interactions in soil environments. The process integrates chemical reaction engineering principles kinetic modelling, emulsion thermodynamics, and semi-continuous reactor operation with microbial compatibility constraints, representing an uncommon and innovative convergence between polymer engineering and agricultural biotechnology. Controlled shear emulsification and residence-time optimization were critical to maintaining matrix porosity while protecting embedded microorganisms. SEM imaging provides direct evidence of novelty, revealing microbial colonization within the matrix, root-hair penetration into the porous structure, and migration of endophytes from the matrix into plant tissues. Field trials across five crops (coffee, banana, Miscanthus, palm oil, maize) demonstrated consistent improvements in growth, biomass, chlorophyll retention, and reduced symptoms associated with *Fusarium oxysporum*. By coupling the matrix with the Symbiotic Rhizosphere Simulated (SRS) system, this work establishes a new integrated platform for agro-process intensification, offering a scalable, biologically active material for next-generation sustainable agriculture.

Keywords

Hydrophilic Microporous Matrix, HIPE Polymerization, PGPR, Endophytes, Rhizosphere Engineering, Process Intensification, Sustainable Agriculture, SRS System, Crop Resilience, Fusarium Suppression