Transforming agriculture: Electrospinning nanobiostimulants for sustainable grow

Antonella Macagnano, IIA-CNR, Montelibretti (RM)

As global agriculture faces pressures to improve crop yields sustainably, the demand for innovative eco-friendly alternatives to traditional agrochemicals is increasing. This study introduces a novel approach to sustainable agriculture through nanobiostimulants made from electrospun nanofibers. By integrating natural resources with advanced biodegradable nanostructured materials, we have developed environmentally friendly products for promoting plant growth.

Leveraging decades of experience in electrospinning technology, we are now applying its versatility to agricultural nanomaterials. Many agricultural practices involve applying various bioactive substances to crops for nutrient support and disease control. The application of nanofibrous structures holds significant potential, as they possess a tunable specific surface area, possibility to combine several materials, allowing for the functionalization of materials to interact with target organisms or to exhibit specific properties. These characteristics are ideal for loading and releasing bioactive substances in a controlled manner to enhance their effectiveness on plants and microorganisms.

This report details our research on utilizing various polymer-carriers, such as polyhydroxy butyrate (PHB) and polycaprolactone (PCL), separately and in blends. We also incorporated natural metal chelating agents, catechol or mugineic acid, to create two nanobiostimulants that facilitate iron transfer to plants with low capacity to mobilize and absorb unavailable iron forms. These nanobiostimulants were tested in hydroponic systems with insoluble iron, showing significant growth improvements in duckweed and tomato plants due to enhanced iron uptake compared to iron-free treatments.

We have recently explored the encapsulation of various bioactive molecules and polymers and organic and inorganic nanoparticles within electrospun nanofibers, generating complex nanobiostimulants with diverse architectures. For example, we extracted polymers (lignin and cellulose) and bioactive compounds (polyphenols) from agro-industrial waste (e.g., from hazelnuts, breweries, and vineyards) to create value-added agricultural products while adhering to circular bioeconomy principles. We designed different architectures (monolayers, multilayers, and 3D structures with varying porosity and mechanical properties) and formulations. These matrices, which include polymeric and nanoparticle lignin and polyphenols, have been assessed for typical features of biostimulants like antioxidant and antimicrobial activities against common phytopathogens.

In conclusion, we emphasize the potential for developing new classes of nanobiostimulants as eco-friendly alternatives to synthetic agrochemicals. This innovation could mitigate traditional agrochemicals' adverse environmental and health impacts and foster sustainable agricultural practices.