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A sustainable model for agriculture based on nanofibrous biodegradable polymers mimicking natural strategies

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The damage and risk to the environment and human health consequent to traditional agricultural practices urged the development of innovative techniques and more environmentally friendly processes and compounds. Nanotechnology can improve the precision in the processes and the coordination of the management strategies of agricultural production. Therefore, innovative and groundbreaking tools have recently been developed employing natural and engineered nanomaterials to deliver agrochemicals to plants for both improving nutrition, stimulate plant growth, improve the quality of the soil and protect plants, while reducing the impact of these compounds on the environment and human health. Electrospinning (ES) is a highly versatile and inexpensive nanotechnology that allows to design and fabricate continuous non-woven polymer fibers with diameters ranging from micrometer to nanometer when a strong electrical field acts on a droplet of a solution with sufficient viscoelasticity. The resulting fibers can assume complex shapes, creating a multitude of structures with a broad spectrum of different properties (porosity, permeability, high fiber interconnectivity, nano-scale interstitial spaces, biomimetism and bioinspiration, etc.).
Since the limitation of iron availability is a crucial condition in plant nutrition, the polymer fabrics here proposed, mimicking the natural strategy adopted by nongraminaceous and graminaceous species (Strategy I and II, respectively), were designed to make available to the plants the insoluble iron (Fe III) widely present in ecosystems by releasing selected iron-chelating molecules. Therefore, we investigated a model system based on ES biodegradable nanofibrous textiles with different shapes capable of releasing natural iron-chelators into soil/water by controlled rates (depending on the membrane morphology). The present study first focused on the production and functionality of a biodegradable nanofibrous polymer (polyhydroxybutyrate-PHB) scaffold, that is naturally produced by microorganisms and algae). Because of its fragility, PHB was then blended with another biodegradable polymer (polycaprolactone-PCL), and then properly bio-loaded. The resulting polymer blend, due to the physical properties of PCL, resulted softer and mechanically more resistant than the previous one (PHB) and it was poorly affected by sudden changes in temperature. Both polymers are water insoluble and present low environmental impact, and are commonly investigated and used in drug delivery structures. The effectiveness and toxicity of both functional systems mimicking Strategy I and II concepts and dynamics were tested in two different plant hydroponic cultures. Such regenerative and sustainable agricultural practices based on natural sources and waste reduction, inspired by the principles of a circular bio-economy

(European Environment Agency, report n. 2/2016), aimed at replacing the use of chemicals and traditional raw materials, improving health and environmental conditions, as required by the original principles of a circular economy, and at facing the increasing risk level for our natural capital.