Soil biodegradation of nutrients enriched cellulose- and chitosan-derived mulching films for sustainable horticulture

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In 2019, global plastics production reached 370 million tons, of which 58 million tons were in Europe[1]. If the plastic use in agriculture accounts for 2% of the global production[2], more than 7 million tons of plastic were used in 2019 in the agricultural sector. Mulch films represent the major source of plastic contamination in agricultural soils[3]. The agricultural surface area covered by plastic films in Europe is four times larger than that covered by greenhouses and six times that of low tunnel hoops. Over the past decades, biodegradable biopolymer mulching films (BPMFs) have been developed to reduce soil pollution by non-biodegradable plastic debris[4] and to expand the circular bioeconomy[5]. In Europe, since 1999, low density polyethylene mulches (LDPMs) have to be dismissed after their use to remove source of pollutants that can reach up to 200 kg ha^{-1}[6] and decline soil quality, crop growth, and yield[7]. BPMFs are a sustainable alternative to conventional LDPMs. Unlike LDPMs, BPMFs, at the end of their lifetime, are tilled into soil where they are expected to be biodegraded by soil microorganisms[8]. Moreover, BPMFs show an estimated saving of about 500 kg of CO_2 equivalent per hectare in comparison with LDPMs. Conversely, the impact of LDPMs in intensive horticulture could result higher than weed control by herbicides as by life cycle assessment (LCA)[9]. BPMFs can be obtained by thermo-plasticizing, solvent casting and spraying processes by using renewable and biodegradable raw materials such as starch, cellulose, chitosan, alginate, glucomannan[10] and glycerin as plasticizer[11]. Cellulose and chitosan, being the two most abundant natural biopolymers on Earth, have been proposed as the best candidates for BPMFs production. Unfortunately, the high tendency for intra- and intermolecular hydrogen bonding confers undesirable mechanical properties. The addition of plasticizer as well as fillers overcome this problem[12] modifying mechanical and functional properties of the materials. To sum up, biopolymer blending is an effective strategy to reuse cellulose and chitosan-containing by-products and develop materials with novel mechanical characteristics[13]. Moreover, the functional properties of these materials can be tuned by doping them with suitable compounds[14]. Based on what stated above, and considering that soil fertility, crop growth and yield, are generally N and P limited, the core idea of this project is the preparation of N- and P-enriched BPMFs for soil mulching, in order to slowly release soluble nutrients into soils upon their biodegradation. The latter aspect is of great importance because a proper C:N:P ratio can lead to an increase of soil-dwelling organisms thus contributing to nutrient cycling in the soil-plant system, soil C sequestration and biological fertility status[15]. Moreover, repeated additions of BPMFs over long term can increase the amount of nutrients, thus reducing the use of external inputs (e.g. synthetic fertilizers) within a circular economy perspective. The specific aim of the proposed research are:

i) to set up a method for the preparation of suitable BPMFs enriched with N and P;
ii) to characterize novel BPMFs and evaluate their structure, degradation kinetics, and isotopic composition
iii) to assess the impact of the innovative BPMFs on soil nutrient cycling and crop growth and yield;
iv) to evaluate the effect of the innovative BPMFs on soil prokaryotes and micro-arthropods communities;
v) to speed-up the biodegradation of the innovative BPMFs by spraying them at the end of their lifecycle with selected microorganisms and by adding the recipient soil with earthworms;
vi) to evaluate the innovative BPMFs using the LCA methodology and to investigate its role within the circular economy.

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