Use of biodegradable plastic films in agriculture and their fate in soil

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Plastic materials such as mulch films are widely used in agricultural applications to contribute toward food security for the growing world population. Global interest in the use of biodegradable instead of non-biodegradable polymers in agriculture has increased in recent decades due to the potential reduction in the accumulation of plastics in the environment. After usage, biodegradable mulch films are intended to be composted or tilled into the soil to decompose into carbon dioxide (CO_2) and water or be incorporated into microbial biomass. Applying biomass-derived biodegradable mulch film not only reduces waste and saves labour, but also reduces greenhouse gas emissions in the agricultural sector, leading to a circular economy (Figure 1). To be more widely adopted, biodegradable mulch films must have the same advantages as conventional plastic mulch films, *i.e.*, increased soil temperature, reduced weed pressure, water retention, reduction of certain pests, increased yields, and more efficient use of soil nutrients.

This topical collection of the *Italian Journal of Agronomy* entitled '*Use of biodegradable plastic films in agriculture and their fate in soil*' consists of five articles, providing scientific evidence on the performance and microbial biodegradation processes of mulch film in agricultural soils. It also provides a thorough discussion on the need to couple direct and indirect methods of to access biodegradation and the overall sustainability of biodegradable plastic mulch films.

Di Mola *et al.* (2022) showed that the impact of biodegradable mulch in terms of yield quantity and quality was comparable to conventional low-density polyethylene (LDPE) films under lettuce production trials in Italy. The authors recommended biodegradable mulch films as they reduce the economic and environmental costs of removing and disposing of LDPE films. Sintim *et al.* (2022) compared the modulation of gas exchange and soil microclimate under biodegradable plastic mulch to those under polyethylene (PE) and paper mulches. Gas exchange under biodegradable plastic mulch was lower than PE mulch in terms of CO_2 accumulation and oxygen reduction in the soil, although this did not affect sweet corn growth. PE mulch conserved soil moisture and inhibited light penetration more effectively than biodegradable plastic mulch. These findings by Sintim *et al*. (2022) demonstrate differences in gas exchange and soil microclimate dynamics between biodegradable plastic mulch and PE, highlighting the need to improve on current industrial products.

Francioni *et al.* (2022) provided a review of the methods used to estimate the biodegradation of biodegradable plastics in the soil, under both laboratory-controlled and open-field conditions. From the review, it emerged that many articles do not report soil characteristics. Moreover, indicators such as mass loss or visual assessment can be useful in open-field experiments as long as they are used on materials already certified as 'soil-biodegradable' following international standards. This is because mass loss or visual assessment indicates degradation and not necessarily biodegradation that requires the mediation of microorganisms. The authors also highlight that there is an urgent need for a shared methodology to make results comparable among different experiments.

Tsuboi *et al.* (2022) evaluated the degradation of three different biodegradable films using the mesh bag method by analyzing the loss of weight and visual area in a cultivated field in Japan over seven months. Among five *p*-nitrophenyl (*p*NP) fatty acid substrates investigated to evaluate esterase activity in the soils, three *p*NP substrates with shorter acyl chains (*p*NP–C2, –C4, and –C6) indicated an increase in hydrolytic activity with film degradation. In particular, *p*NP–C4 hydrolytic activity can aid in the detection of the microbial activity associated with the biodegradation of polyester-based biodegradable mulch films in cultivated field soils.

Bianchini *et al.* (2022) conducted open-field experiments where they evaluated the effects of soil refinement on the degradation rates of three different commercial soil-biodegradable mulch films after their incorporation into the soil. Their results show that soil refinement significantly accelerated the degradation of the tested films. Although this appears to be the first study to evaluate the effect of different soil management under open-field conditions, future studies are needed to quantify the biodegradation of polymers over time following international standards.

The articles published in this topical collection highlight several aspects of the use and biodegradation of soil-biodegradable plastics in agriculture. We expect that this collection will act as a stimulus to advance research and development in biodegradable

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Italian Journal of Agronomy 2022; 17:2155
doi:10.4081/ija.2022.2155

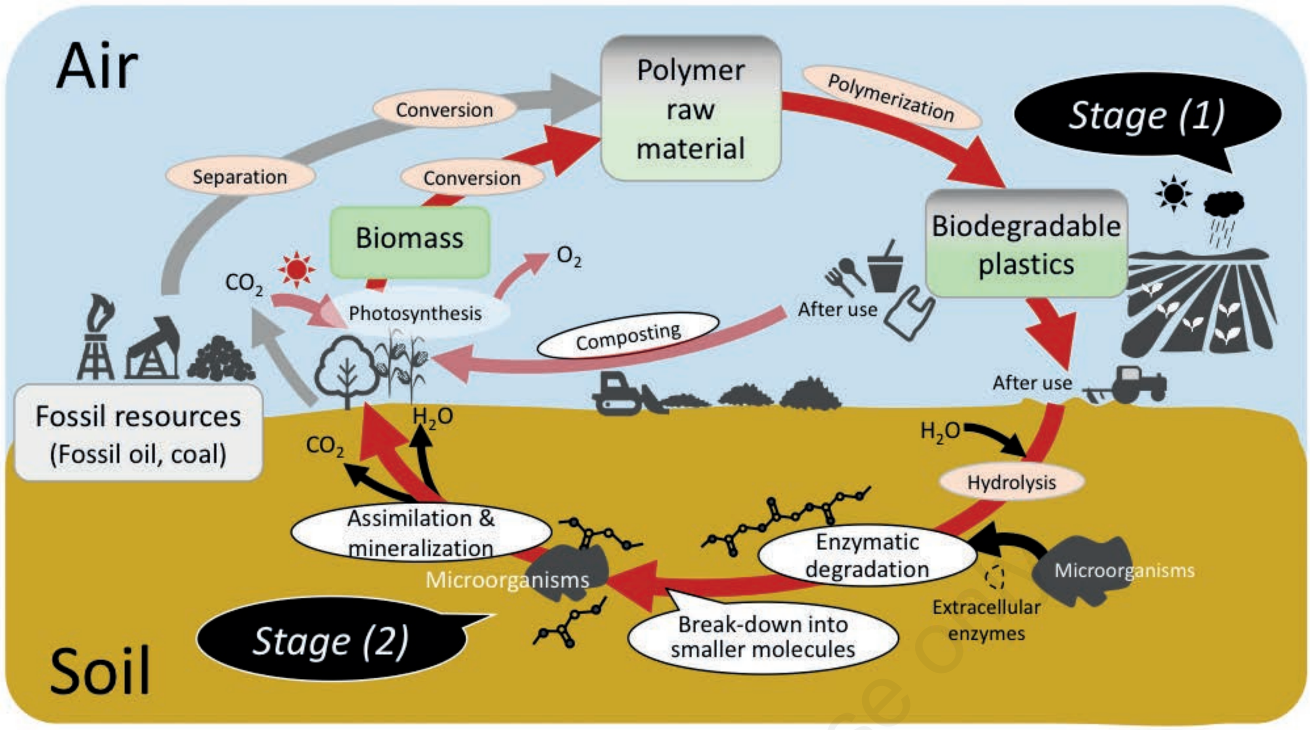

Figure 1. Biodegradable plastic products derived from fossil resources and biomass and their use in agriculture. Two stages are the key to promote biodegradable mulch films as an alternative to conventional polyethylene (PE) films in agriculture: (1) cost-effective crop growth equal to or greater than that achieved by PE films, and; (2) ensure safe application including desirable biodegradation in soils.

plastics. This could potentially switch plasticulture towards the use of soil-biodegradable plastics in comparison to the non-biodegradable plastics that currently dominate agricoltural use. Such an endeavour would facilitate the achievement of food security with greater environmental sustainability. Future research should focus on topics related to the two stages in Figure 1, such as: i) multi-year/site experiments to help improve biodegradable plastic products for crop yield and quality; ii) novel and improved methodologies for quantifying biodegradation in soils; and iii) creating tools to predict biodegradability based on site-dependent soil properties and climatic factors.

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