Abstract of Research Project
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BIOPLASTICS EFFECTS ON SOIL QUALITY: A RESEARCH ON THE INTERACTIONS BETWEEN THE POLYMERS DEGRADATION AND THE PHYSICAL, CHEMICAL AND BIOLOGICAL PROPERTIES OF SOIL

The continuous innovation of polymeric technology and manufactured plastic helps to explain why plastic production has increased on an average of almost 8,4% every year on a global basis (Geyer et al., 2017). From around 1.3 million tons in 1950, the total global production of plastic has grown to 359 million tons in 2018 [PEMRG]; only 15% of the overall amount of plastic waste produced is actually recycled, while the remaining fraction is partly processed by incinerators or waste to energy plants (25%), landfilled (60%) or released to the environment (OCSE 2018). Uncontrolled disposal of plastic may cause severe and diffuse damages to the landscape, to the environment, to the agricultural soil, to the atmosphere, to the surface and groundwaters. In fact, the interaction between plastics and environmental conditions (e.g. wind, rain, light) causes the degradation of the polymers, which results in weakening the polymers's chain and thus creating even more persistent and little particles (Folino et al., 2020).
The problems linked to plastic wastes led to the development of bioplastics, a whole family of materials with different properties and applications.
According to European Bioplastics, a plastic material is defined as a bioplastic if it is either bio-based, biodegradable, or features both these properties.
There are three main groups of biodegradable plastics:

- Bio-based or partially bio-based non-biodegradable plastics such as bio-based polyethylene (bio-based PE), polypropylene (bio-based PP), or polyethylene terephthalate (bio-based-PET) and bio-based technical performance polymers such as polytrimethylene terephthalate (bio-based PTT);

- Plastics that are both bio-based and biodegradable, such as polylactic acid (PLA), polyhydroxyalkanoates (PHA) and polybutylene succinate (PBS);

- Plastics that are based on fossil resources and are biodegradable, such as polybutylene adipate terephthalate (PBAT).

In this research, the biodegradable bioplastics will be deeply studied; these materials can be described as a family of polymers that can be mineralized into carbon dioxide, methane, water, inorganic compounds or biomass through enzymatic action of specific microorganisms.
Awareness of the impact on the environmental waste problem has awakened research in the ambit of biodegradable plastics. In fact, numerous studies have analyzed the process of degradation and biodegradation of bioplastics, both in aerobic and anaerobic conditions.
Already in 2007, Mohee et al. affirm that the environmental degradability of plastics is a complex process that is influenced by the nature of the plastics themselves and by the conditions to which they are exposed.
The rate of biodegradation is, in fact, affected by the combination of polymer characteristics (e.g., surface conditions, first order structure and high order structure), abiotic reactions (e.g., photo-degradation, temperature, humidity) and by the microorganisms responsible for the enzymatic cleavage (Bátori et al., 2018; Thakur et al., 2018). Microbial characteristics, affecting the biodegradation rate includes: the type of microorganism present in the matrix, the microorganism distribution, the microbes growth conditions (pH, temperature, moisture content, oxygen and nutrients presence) and the types of enzymes produced by the microorganisms (intracellular, extracellular) (Mehdi Emadien et al., 2017).
The research is focused on evaluating the biodegradation of bioplastics in soil. Sintim et al. (2020) conducted in situ evaluations of the degradation of soil-biodegradable plastic mulches in agricultural soils at two locations; they found that it takes several years for soil-biodegradable plastic mulches to attain 100% degradation. Also, Sintim et al. (2019) observed that while the polymers of biodegradable plastic mulch deteriorates, micro and nano-sized particles, such as carbon black, were released during degradation in compost, suggesting the need for studies to determine whether their use could elicit unintended consequences. However, short-term studies indicate that soil-biodegradable plastics pose minimal risk to soil physical, chemical, and biological properties (Sintim et al., 2019; Bandopadhyay et al., 2020; Bloecker et al., 2020).

The main objective of this research is to investigate the interactions between physical, chemical and biological properties of the soil and the rate of biodegradation of bioplastics.
The use of bioplastics in agriculture will be assessed using the Life Cycle Assessment (LCA) as environmental performance's indicator.

This research will compare the degradation's rate of selected bioplastics, non-biodegradable plastics and cellulose, as reference material (100% soil-biodegradable). Furthermore, samples with no treatments will be used as non treated control.
Soil samples (0-15 cm soil depth) will be collected from an olive grove in Bevagna (Perugia, Italy) (12°59′E, 42°92′N). The orchard consists of adult plants (about 30 years old) of Frantoio cultivar with a spacing of 6 x 6 m. The area is characterized by a temperate-sublitorial climate and the average difference between the temperatures recorded in the coldest month (January) and the hottest month (July) is 19-20°C.
The collected soil (sieved at < 2 mm) will be weighted and transferred to capped glass cylinders (200 gr/jar). The polymers will be buried and well mixed into the soil, while the amount of material to be used in the experimentation will be chosen according to the amount indicated in literature. Soil moisture will be adjusted to 60-75% of soil's water holding capacity and cylinders incubated at 20°C in the dark. Experimental tests will be done under controlled conditions.

Soil properties will be first characterized at the beginning of the experiment and then evaluated at specific sampling times (1 day-7 days-14 days-45 days-60 days-90 days-120 days-360 days). The measured physical and chemical soil properties include aggregate stability, soil resistance to penetration, bulk density, infiltration, soil pH, electrical conductivity, total organic carbon (TOC), total exchangeable carbon in alkalis (TEC), dissolved organic carbon (DOC), specific UV absorbance at 254 nm (SUVA 254), soil humic substances, total N, dissolved organic carbon (DON), assimilable P and exchangeable K.

Soil microorganisms will be studied through the application of culture-independent techniques based on the extraction of bacterial and fungal DNA from the soil matrix. This analysis will qualify the species that colonizes the soil and will evaluate the effect of plastics and bioplastics contamination on soil microbial population.

Moreover, to determine the microbial activity at every experimental time, both soil respiration (as CO_2 evolution using alkaline traps) and enzyme activity will be measured.

Ecotoxicity tests will be conducted on soil during and after the degradation of polymers, to make sure that products of degradation do not affect the environment and soil quality. Adopted tests will follow the iter of the Italian Institute for Protection and Environmental Research (ISPRA).

The aim of the research is to understand if polymers addition to soil negatively influences soil quality and the ecosystem services.

Ecotoxicological tests are internationally known as complementary tools of physical-chemical analysis to evaluate soil contaminations. In fact, the soil's physical-chemical characterization doesn't allow, by itself, to express any kind of danger regarding the living communities; it is indeed necessary to include biological parameters in these investigations, inasmuch the biological effect is linked to the bioavailable fraction of the pollutants which, furthermore, depends on chemical and environmental conditions of soil (Clasen et al., 2019).

Nowadays plastic polymers are ubiquitous materials in our economy and daily lives but often the policies adopted for the plastic recovery are not totally efficacious.

It is therefore necessary to continue to research the effects of polymers in the environment to guarantee a sustainable use of plastics.

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