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Insight of Environmental Microplastics Responsive to Agricultural Ecosystem

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Abstract

With the investigation of Microplastics' distribution in the environment, and the experiment of biotoxicity exposure, the pollution of microplastics has become one of the hot environmental issues. A large number of studies have shown that microplastics have a great impact on the terrestrial ecosystem. In this paper, the source of microplastics in soil environment and agricultural system, and the reaction of microplastics pollution to plants are reviewed in combination with the research papers published in recent years.

Introduction

Plastics are widely used in modern society because of their durability, cheapness, and ease of production. Under the action of physical erosion, biodegradation, or photocatalytic oxidation, the plastics entering the environment can be degraded into microplastics, with a diameter of < 5 mm, [1]. Microplastics refer to the plastic fibers, particles, or films in the environment. The main components include polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), polylactic acid (PA), and polyethylene terephthalate (PET), etc., which are all over the ocean, land, and atmosphere, thus, it is a serious environmental pollution problem derived from "white pollution" [2]. It is reported that global annual plastic production has far exceeded 300 million tons [3], among which nearly 80% of plastic products are released into landfills or the natural environment without effective treatment, causing serious environmental pollution problems [4].

Source of Microplastics

Since the 1950s, all kinds of plastic products have been produced continuously, and the output of plastic shows an exponential growth trend. In 2015, the global output was 322 million tons, and the total output is expected to reach about 600 million tons by 2025 [5]. Microplastics can come from both terrestrial and marine sources, and land-based microplastics waste accounts for about 80 percent of the total plastic waste in marine ecosystems [6]. It is reported that the global production of microplastics reaches 3 × 109 tons per year [7], and it is expected that by 2050, 1.20 × 1011 tons of microplastics waste will accumulate in landfills or natural environments, causing serious plastic pollution around the world [4].

Research on Microplastics in Soil Environment and Agricultural Systems

Compared with the aquatic ecosystem, few pieces of research available on microplastics in the soil ecosystem [8-10]. Soil is the basis of material exchange and is closely related to human life. It has been reported that agricultural soils may even store more microplastics than the oceans due to the recycling of organic waste containing microplastics and the extensive use of plastic film [9,11]. Microplastics enter agricultural soils mainly through aerial deposition, landfills, irrigation water contaminated with microplastics, residues of plastic mulch used in agricultural or horticultural products, and sewage sludge deposition [12]. After entering the soil,

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microplastics can change the soil's physical and chemical properties, and then have adverse effects on soil biology [13,14]. A study estimated the maximum microplastic load in agricultural ecosystems in Europe, North America, and Australia. It found that the microplastic load from organic waste recycling alone was as high as 2.8 ~ 63 t/hm^2 [12]. Studies have shown that microplastics in agricultural ecosystems can reduce soil microbial biomass and reduce soil microbial activity and functional diversity and even further affect the cycling process of plant nutrients in soil [9,15], which may indirectly affect plant seed germination and seedling growth.

The Response of Plants to Microplastics Pollution

Uptake of micro- and nano-plastics by plants

Due to anatomical and physiological variations, there are differences in the uptake, transport, and accumulation of plants' pollutants. It is known that nano-plastics affect plant root properties (volume, density, surface area), xylem properties (volume, surface area), transpiration, growth rate, water, and lipid composition, plasma membrane potential, vacuolar membrane potential, cytoplasmic pH and vacuolar pH [12]. There are few studies on the transport and accumulation of small size microplastics (nano-plastics) in plants. However, the use of fullerene C70 in rice [16] and carbon nanotubes in soybeans, corn, rice, and Arabidopsis arabidopsis have demonstrated engineered transfer carbon nanoparticles in the 40-70 nm range across stems and/or leaves [17]. Because of their smaller size compared to microplastics, nanoplastics have been shown actually to enter plant cells. Bandmann, et al. demonstrated that 20 and 40 nm polystyrene beads were endocytized by tobacco BY-2 cells in cell culture [18]. Previous studies of Chinese scholars have shown that lettuce can absorb and accumulate 0.2 μm polystyrene microplastic under hydroponics conditions and transport them to the stems and leaves [19]. It is also shown that submicron microplastics and even micron microplastics (2 μm) can enter the plant body through the gap formed during the growth of lateral plant roots [20].

Toxicity, stress, and response of plants to microplastics

Yuan, et al. has reported that ground-based plants are the basis of many food chains, so the accumulation of nanoplastics in plants may affect other nutrient levels, which may pose potential risks to food production, quality and safety. Microplastics in the soil can bring potential health risks through the food chain and enrichment [21] and affect the growth and development of crops. Different types and concentrations of microplastics will influence the growth of crops. Referring to wheat, when the microplastic concentration was lower than 500 mg•L^{-1}, ethylene-vinyl acetate copolymer, linear low-density polyethylene, and methyl methacrylate inhibited the germination of wheat [22-24]. Studies of other land plants have shown that the 0.1 μm polystyrene microplastics under hydroponics conditions could be absorbed and accumulated by the root system of broad bean and interfere with the transport of nutrients and produce genotoxicity [10]. Other studies have shown that microplastics can block the pores of hemlock seeds and inhibit water absorption, thereby delaying germination and root growth [25]. Microplastics of different sizes have different effects on plants. The toxicity of microplastics with small particle size was stronger.

Microplastics at 100 nm (100 mg•L^{-1}) had an inhibitory effect on the growth of vicia faba. The 100 nm polystyrene (PS) microplastics can block the pores in the cell wall and intercellular connections, affecting nutrient transport. Simultaneously, it was found that microplastics at 100 nm had stronger genotoxicity than those at 5 μm [26]. By studying the effects of microplastics on Arabidopsis thaliana, Sun, et al. also found that there are signs that the nanoplastics are preventing the normal growth of plants and damaging the development of seedlings. In worst case, the team believes that the plastics are altering the genetic makeup, and that the RNA sequences they obtained from the plants suggest that the nanoplastics may be damaging the plants' ability to resist disease [27].

Conclusions, Knowledge Gaps and Future Area of Research

Plants are the outset of ecosystem production and bioaccumulation. The absorption and transfer of microplastics by plants is the key for microplastics to enter the food chain through plants. A few studies have shown that microplastics can enter plants during their growth and potentially affect the quality safety and nutritional quality of agricultural products for human consumption. However, few reports are available on the effects of microplastics on seed germination, seedling growth, and physiological characteristics. Simultaneously, whether microplastics pose a risk to human health in soil-plant systems and through food chains remains to be further explored.

Microplastics may enter the human body through the food chain and harm the health, but researches on the mechanism of microplastics entering plants and the migration, distribution, and transformation of microplastics in plants, and some related fields are inadequate. Therefore, less attention has been paid to plant cultivation and safety in the field of microplastics pollution. In short, the research on the harmful effects of microplastics in the environment on plants and even human health is still in its infancy, and more comprehensive and systematic studies are needed.

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