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Research Progress on The Effects of Microplastics on Soil Carbon Recycling and Microorganisms in Farmland

Hua Zhuang[1, 2, 3, 4, 5], Yang Zhang[1, 2, 3, 4, 5]

[1]Shaanxi Provincial Land Engineering Construction Group Co., Ltd.China.

[2]Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd.China.

[3]Key Laboratory of Degraded and Unused Land Consolidation Engineering, Ministry of Natural Resources.China.

[4]Shaanxi Engineering Research Center of Land Consolidation.China.

[5]Land Engineering Technology Innovation Center, Ministry of Natural Resources.China.

Abstract

In recent years, the problem of microplastic pollution in farmland soil has attracted more and more attention. It has become a hot issue in global environmental pollution. In order to achieve high yield and increase income, people put a lot of plastic film into use, and it is difficult to achieve complete recycling in the use process. A large number of residual plastic film can be broken or degraded into microplastics with particle size less than 5mm by physical, chemical and biological processes in farmland ecosystem. In this paper, we reviewed the effects of microplastics pollution on carbon recycling of farmland soil and soil microorganisms in recent years, including the following aspects: (1) The effects of microplastics on soil ecosystem; (2) the effects of microplastics on soil carbon cycling; (3) the effects of microplastics on soil microbial community. Finally, we prospected the key directions for future research on microplastics in farmland soil.

Keywords

Microplastics pollution, Carbon cycling, Microbial community.

1. RESEARCH BACKGROUND AND SIGNIFICANCE

As an important part of terrestrial ecosystem carbon pool, farmland soil carbon pool plays an important role in mitigating climate change and ensuring food security. Therefore, soil carbon transformation in cropland ecosystems has become one of the important fields in the current study of terrestrial ecosystem carbon cycle [1-2]. Studies have shown that soil microorganisms affect many ecological processes closely related to soil carbon cycling, such as carbon fixation, methane metabolism, and carbon degradation, by changing their own metabolic activities such as enzyme secretion and respiration [3]. In cropland ecosystems, soil microorganisms decomposed crop residues to form organic carbon, and converted organic carbon to inorganic substances and CO2 through mineralization and respiration.

However, in order to achieve high yield and increase income, a large number of plastic films are used to achieve soil moisture and temperature retention, inhibit weed growth, etc[4]. Plastic film is usually transparent polyethylene film (PE), which is essentially fossil carbon stored in the form of polymer[5]and difficult to be completely recovered during use. A large amount of residual plastic film is equivalent to introducing a large amount of additional carbon sources to cropland ecosystems, but it is not clear how this additional carbon source affects soil carbon

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cycling [6-7]. In recent years, the global area of plastic film mulching has increased at an average rate of 1.5 million tons/year, rapidly covering agricultural areas all over the world [8]. Due to the lack of mature plastic film recycling system at present, a large amount of plastic film remains in the soil. These plastic residual films were broken or degraded into microplastics (MPs) with particle size less than 5mm by physical, chemical and biological processes [9]. The survey results show that about 95% of the residual film particle size in farmland soil in China is 0.05-1mm, which indicates that MPs is the main form in farmland soil covered with film[10] Studies have shown that MPs can change soil physical and chemical properties (pH, water cycle, bulk density, etc.), thereby further changing the structure and functional composition of microbial communities [11]. MPs can also induce changes in some soil biochemical processes by changing the growth and metabolic activities of soil microorganisms[12]. For example, in paddy soil, MPs promoted the mineralization of organic matter by reshaping soil microbial communities[13] In addition, some scholars have pointed out that MPs, as a new artificial carbon source, is composed of more than 80% carbon [14]. In soil, it can be integrated with other organic matter into soil aggregates and disguised as soil organic carbon (SOC) (Rillig, 2018), but it does not have similar ecological functions as SOC[15].

2. RESEARCH STATUS AT HOME AND ABROAD

2.1. Impacts of microplastics on soil ecosystem

Studies have shown that MPs can change soil physical and chemical properties, such as soil pH, soil aggregates, and soil bulk density [16], soil structure, and water cycle, which in turn affect plant growth and development[17]. Under the combined influence of soil leaching, animal disturbance, and agricultural operations, MPs can migrate horizontally or vertically in the soil layer, further aggravating the deterioration of farmland quality [18-20. In addition, plastics can adsorb organic pollutants[21, such as organochlorine pesticides[22] due to their unique surface properties, such as hydrophobicity and high specific surface area[23]. Therefore, in the soil ecosystem, MPs can, on the one hand, act as carriers to transfer various pollutants into the soil biota, thereby causing harm to the soil ecosystem[24]. On the other hand, the continuous accumulation of MPs can affect the structure and function of soil microorganisms and the normal growth of plants [25]. For example, it can delay the germination of plant seeds[26] and inhibit the normal growth and development cycle of the above-ground and underground parts of plants[27] . A growing number of studies have shown that MPs in soil can be adsorbed by plant roots to cause oxidative stress damage[28], or can be taken up by plants and enter the food chain[29] .

2.2. Effects of microplastics on soil carbon cycle

Some scholars have pointed out that MPs can provide a new niche for various soil microorganisms because its surface can be colonized by a variety of microorganisms, which has led to the emergence of a new concept of "plastisphere"[30]. As a new growth substrate for microorganisms in the soil environment[31] , this means that MPs in farmland can be used as a potential carbon source for soil microorganisms, thereby changing the flow pattern of soil carbon. For example, in cropland ecosystems, MPs in soil can inhibit the activity of β-glucosidase and alter the flow of carbon in plant-soil systems, indicating that MPs may affect a range of carbon-dependent soil ecological functions. Recent studies have shown that MPs can affect genes involved in soil carbon cycling. The relative abundance of carbon fixation genes (cbbL) and carbon hydrolase genes (β-glu and chi-A) in the mulched soil decreased by about 50-80% compared with that in the non-mulched farmland soil [32]. In addition, MPs can be gradually immobilized in soil by combining with soil minerals or organic compounds through biotic and abiotic processes. These carbon compounds are then locked into soil aggregates, physically protected from microbial decomposition and contributing to the formation of macromolecules,

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known as aromatic compounds, It can change the storage of soil organic matter (SOM)[33], and then change the carbon allocation pattern of the belowground part of plants (Chen et al., 2020). For example, it has been pointed out that polyvinyl chloride (1-5%) powder can change the carbon allocation pattern in wheat soil by stimulating root growth and enhancing root deposition.Other scholars pointed out that the effect of MPs on enzyme activities of viscous soil in southwest China may be dependent on SOM[34].

2.3. Effects of microplastics on soil microbial communities

Soil microorganisms are extremely sensitive to environmental factors. Therefore, changes in soil physicochemical properties by MPs are bound to affect the structure and function of soil microbial communities. Ng et al. (2021) showed that the addition of 3% LDPE reduced the Alpha diversity of soil microorganisms. Wang et al. (2020a) conducted a simulation study and found that the succession rate of MPS-modified soil was significantly higher than that of control samples, indicating that the presence of MPs in the soil ecosystem may accelerate the succession rate of soil bacterial communities. The community composition and diversity of arbuscular mycorrhizal fungi (AMF) also changed strongly under the disturbance of MPs, and the intensity of the change showed a certain characteristic of MPs dosage effect[35]. The generalisability of the above findings implies that MPs may affect nutrient cycling as these symbionts transport nutrients to their plant hosts[36].

In addition to its effects on soil microbial community structure, MPs can also alter the metabolic activities of soil microorganisms. However, this effect is related to the type and concentration of MPs. Some studies have found that 0.1% polyacrylic acid and polyester fibers can reduce the metabolic activity of microorganisms[37], but 0.4% polyethylene film fragments only caused a weak change in soil microbial community structure [38].. However, 10% polyvinyl chloride and polyethylene powder could change the dominant bacteria of wheat soil microbial community from Gram-positive bacteria to negative bacteria, and reduce the activities of β-glucosidase and xylosidase by 16-43% . In acidic farmland soils, both 1% PE and 5% PVC reduced the richness and diversity of bacterial communities, inhibited the activity of fluorescein diacetate hydrolase, and stimulated the activities of urease and acid phosphatase[39].Other studies have shown that MPs can interfere with carbohydrate metabolism and hormone regulatory network in barley, which may be related to the large amount of carbon in MPs[31]. Soil enzyme activity is key to soil microbial processes. On the one hand, MPs could change soil physical and chemical properties and the ecological function of microbial communities in farmland systems. On the other hand, MPs may act as a new artificial carbon source as a potential substrate to affect the activity of enzymes, thereby changing the metabolic capacity of soil microorganisms[40] .

Some studies have pointed out that with the increase of residual film amount, the quality of soil arable land decreases. Dong Hegan et al. (2013) and Zumilaiti Tulgan et al. (2017) emphasized that MPs severely restricted the nutrient utilization rate and the normal development of cotton root system in the arid region of Xinjiang. In addition, as carbon chain polymers, the accumulation of MPs is bound to affect soil carbon pool in farmland in arid region of Xinjiang. Given the important role of soil carbon pool in the global carbon cycle in arid regions, it is important to understand the key microbial processes of soil carbon cycling by MPs.

3. DISCUSSION

A large amount of residual plastic film in farmland soil is broken or degraded into microplastics with particle size less than 5mm, which greatly changes the farmland soil environment. Soil microorganisms play an important role in several key processes of carbon cycling in terrestrial ecosystems, and are also extremely sensitive to changes in environmental factors. In cropland ecosystems, soil microorganisms decomposed crop residues to form

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organic carbon, and converted organic carbon to inorganic substances and CO2 through mineralization and respiration. However, in order to achieve high yield and increase income, a large amount of plastic film has been used, and residual plastic film is equivalent to introducing a large number of additional carbon sources for farmland ecosystems. Plastic has become an indispensable product and is widely used in modern society, and plastic pollution has become a global environmental pollution problem.

Plastic film is usually transparent polyethylene film (PE), which is essentially fossil carbon stored in the form of polymer and difficult to be completely recovered during use. A large amount of residual plastic film is equivalent to introducing a large amount of additional carbon sources to the cropland ecosystem. It is necessary to understand how this extra carbon source affects the microbial process of soil carbon cycling as soon as possible[6-7].

At present, the research on MPs at home and abroad mainly focuses on the water environment, while the systematic research on MPs pollution in terrestrial ecosystems, especially soil environment, started relatively late [41].Farmland ecosystem in arid area occupies a large part of farmland in China. However, there is still a lack of research on the ecological effects of MPs pollution. In view of the vulnerability of farmland ecological environment in arid regions, it is urgent to strengthen the research on the effects of MPs on farmland soil environment in arid regions in the future. It would help to comprehensively assess the ecological risks of microplastics on farmland soil environment in arid areas, and provide a new scientific basis for carbon sequestration and emission reduction of green agricultural industries in arid areas. This study laid a foundation for understanding the mechanism of microplastics on soil carbon cycling.

Studies have shown that both microbial and enzymatic activities have important effects on the recycling and storage of SOM, which plays an important role in maintaining soil quality and productivity. Arid and semi-arid regions cover about 45% of the earth's surface area. Although the ecosystem has poor water and fertilizer conditions and low productivity, it plays a decisive role in the global carbon budget[42]. Therefore, how MPs affects soil carbon storage and turnover in arid regions should be further studied in the future. Although plastic film has obvious yield-increasing effect on arid and barren farmland due to warming, moisturizing, inhibiting grass and preventing insects[43], it is accompanied by the long-standing problem of "white pollution". It is difficult to completely recycle plastic film during use, and a large amount of retained film seriously affects the green and sustainable development of farmland soil ecosystem[44] . Therefore, under the background of vigorously promoting green agricultural industry, understanding the mechanism of the effects of MPs on farmland soil carbon cycle in the arid region of northwest China would be helpful to correctly assess the effects of MPs on farmland soil carbon pool, and provide a new data reference for carbon sequestration and emission reduction in farmland ecosystems in the arid region of China.

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