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Effects of polyester microfibers on soil physical properties: Perception from a field and a pot experiment

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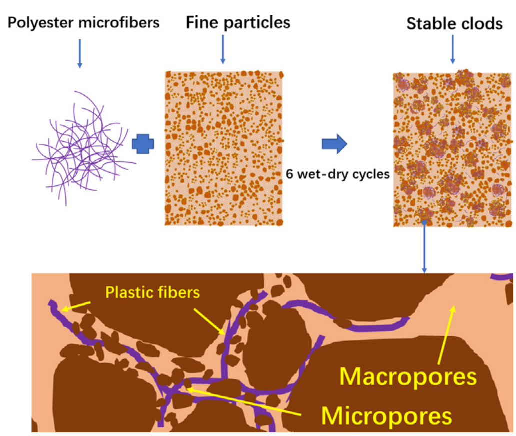
HIGHLIGHTS

- The changes of soil physical properties induced by polyester microfiber were observed from a field and a pot experiment.
- Polyester microfibers did not alter soil bulk density and saturated hydraulic conductivity.
- Polyester microfibers reduced the volume of <30 μm pores as increased the volume of >30 μm pores.
- Polyester microfibers increased soil aggregation in the pot experiment but not in the field experiment.

GRAPHICAL ABSTRACT



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ABSTRACT

Understanding soil physical properties is essential for soil quality management and sustainable land use. With the growing accumulation of microplastics in soils, a better understanding of the impact of microplastics on soil physical properties is crucial to conserve and manage soil quality. This study explored the effects of polyester microfiber (PMF) concentrations (0, 0.1% and 0.3%) on bulk density, porosity, aggregation and hydraulic conductivity of a clayey soil from a field experiment (1 year) and a pot experiment (6 wet-dry cycles). Polyester microfibers significantly increased the volume of >30 μm pores and reduced the volume of <30 μm pores compared to the control treatment. However, there were no detectable changes in the soil bulk density and saturated hydraulic conductivity between the PMF treatments and the control treatment. Interestingly, we observed that polyester microfibers significantly increased the contents of water stable large macroaggregates (>2 mm) in the 0.3% PMF (44%) and 0.1% PMF (39%) treatments compared to the control treatment (31%) in the pot experiment, but this was not true in the field experiment. The efficient interaction between polyester microfibers and fine soil particles and the frequent wet-dry cycles enhanced the formation and stability of macro-aggregates induced by polyester microfibers in the pot experiment. Overall, our results provide valuable evidence for microplastic influences on soil physical properties. Because microplastics are long-term anthropogenic contaminants, it is necessary to further study the impacts of microplastics on soil quality for terrestrial ecosystem sustainability.

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1. Introduction

Microplastic contamination is a growing environmental concern. Because <2% of global plastic waste is discharged directly to the oceans (Van Sebille et al., 2015), the terrestrial ecosystem is acknowledged as the dominant sink and origin of microplastics (Geyer et al., 2017; Horton et al., 2017). However, there is a considerable lack of knowledge on the occurrence, sources and behavior of microplastics in soils (Rillig, 2012; Nizzetto et al., 2016; Rillig et al., 2017a). Microplastics can enter soils via soil amendments, plastic mulching and irrigation as well as other sources, such as diffuse urban runoff, flooding and atmospheric fallout (Kim et al., 2004; Eerkes-Medrano et al., 2015; Dris et al., 2015; Steinmetz et al., 2016; Majewsky et al., 2016; Mahon et al., 2017). Early quantitative evidence for the occurrence of microplastics in soils was described in 2005 (Zubris and Richards, 2005). Recent studies have detected microplastic concentrations in agricultural soils ranging from 7000 to 43,000 particles per kilogram soil (Zhang and Liu, 2018), and 0.03 to 6.7% of soil weight in studied industrial areas comprised microplastics (Fuller and Gautam, 2016). Furthermore, some studies have reported the negative effects of microplastics on soil biota (Kiyama et al., 2012; Lwanga et al., 2016; Lwanga et al., 2017). On the other hand, soil biota also influences the movement and distribution of microplastics in soil profiles (Rillig et al., 2017b; Maaß et al., 2017). Currently, the movement of microplastics and their interaction with soil biota and mineral particles in soils are of particular concern (Rillig et al., 2017a; Bläsing and Amelung, 2018).

Soil aggregate stability often has a great influence on soil quality and functions because it affects physical properties such as infiltration, porosity, erodibility, and the capability of soil to transmit gases and liquids (Bronick and Lal, 2005; Bartoli et al., 2016). It was concluded that soil aggregate formation and stability relied strongly on the complex interactions of soil organic carbon, fine mineral particles and the microbial community (Six et al., 2004; Feller and Beare, 1997; Kögel-Knabner et al., 2008). In addition, the stability of soil aggregates is only temporary and affected by seasonal dry-wet cycles and agricultural practices (Bronick and Lal, 2005; Christensen, 2001). The reduction of aggregate stability can lead to soil structure degradation, such as formation of surface crusts, loss of pore continuity, lower hydraulic conductivity, increased runoff and soil erosion, and nutrient loss.

With the growing accumulation of plastic debris in soil, more microplastics will likely embed within soil aggregates. As sorbent, microplastics can incorporate with soil mineral and organic components and may alter soil aggregation by affecting microbial activity and “packing” effects (Rillig et al., 2017a; Steinmetz et al., 2016; Lei et al., 2018). One study found that the concentration of aggregate-associated microplastics increased as aggregate size decreased (Zhang and Liu, 2018). Another study found that microplastics could affect soil physical properties, but those particles functioned as long-term stressors on soil structure (de Souza Machado et al., 2018). In fact, the consequences of microplastic accumulation in soils is not well known.

Microplastic fiber, which originate from fragmentation and degradation of synthetic fabrics, ropes and nets etc. (Andrady, 2011), is the most frequently detected type of microplastics in the natural environment (Baldwin et al., 2016; Phuong et al., 2016; Zhang and Liu, 2018). Currently, many studies focus on approximately spherical microplastics but no other microplastic types. The abundance of plastic fibers in soils is known (Naji et al., 2017), but quantitative evidence of their behavior is very limited. Therefore, the aim of this study is to determine the effects of fibrous microplastics on soil aggregation, bulk density, porosity and hydraulic conductivity.

2. Materials and methods

2.1. Field experiment setup and sample collection

A field experiment was conducted from June 2017 to May 2018 at the Chenggong experimental station of Yunnan University (24°49′48″ N, 102°51′22″ E). This subtropical area has an appreciable wet (June–October) and dry (November–May) season with 789 mm of annual rainfall and a 14.7 °C average annual air temperature (1981–2010). The soil of the experiment site was classified as a Nitisol (IUSS, 2014). The Nitisol is classified as a clay loam in the 0–20 cm depth with 24% sand, 41% silt and 35% clay, and an organic carbon concentration of 4 g kg^{-1}.

Because polyester fibers, as main synthetic fibers used in the manufacture sector and people's daily life, are prevalent in the environment, our work is focused on the effects of polyester microfibers on soil aggregate stability, bulk density, porosity and saturated hydraulic conductivity. The experiment used a randomized complete block design with three polyester microfiber levels (0 g, 84.77 g [0.1% of soil dry weight] and 254.31 g [0.3% of soil dry weight]) and two organic material levels (0 g and 2543.1 g [3%] of soil dry weight), replicated three times. The upper limit concentration of polyester microfibers was determined based on the maximum concentration at which polyester microfibers could be completely incorporated with soil particles. Each plot was 100 cm long and 100 cm wide and separated by 30 cm high and 40 cm wide ridges. There were 18 plots in total.

For the polyester microfiber treatment, a 100% polyester microfiber mop head (product number HC015326, Hongchang Co., China) was cut manually to obtain fibers. These polyester microfibers had an average diameter of <5 μm and an average length of 2.65 mm (min = 1.17 mm, max = 4.78 mm, $n = 53$). For the organic material treatment, the litter of a *Populus nigra* plantation was collected from an uncontaminated area in Chenggong, China. After cleaned by deionized water, the litter was oven-dried (60 °C) and milled to pass through a 2 mm sieve.

After the polyester microfibers and organic materials were spread evenly on the plot surfaces, all plots were rotary tilled to 7-cm-deep three times to thoroughly mix polyester microfibers and organic materials with the soil. During the experiment, all weeds that occurred in these plots were removed by hand at the germination stage. Soil samples were collected in May 2018 at the end of the dry season. For each plot, three replicates were randomly taken from the 0–5 cm layer using a narrow spade and then mixed to form one composite sample. Soil samples were air-dried, sealed and stored at 25 °C. On the same date, three undisturbed core samples were collected randomly from the 0–5 cm layer in each plot using a stainless ring (200 cm^3) for bulk density and porosity analysis.

Soil saturated hydraulic conductivity (K_{sat}) was measured using a twin ring in May 2018 before soil sampling (Scotter et al., 1982). *Ksat* measurement was replicated two times in each plot. The value of K_{sat} was calculated following the method of Scotter (Scotter et al., 1982).

2.2. Pot experiment setup and sample collection

Subsoil (100–150 cm) was collected from a sloped field at the campus of Yunnan University (24°49′51″ N, 102°51′31″ E) in September 2016. The soil is a Nitisol with a texture of 40% clay, 42% silt and 18% sand, and an organic carbon concentration of 2.0 g kg^{-1}. After collection, the soil was air-dried and passed through a 5 mm sieve to remove gravel and then ground and passed through a 0.25 mm sieve to remove macroaggregates. The <0.25 mm microaggregate, silt and clay fractions were thoroughly mixed and stored before use.

A full factorial pot experiment was designed with three polyester microfiber levels (0, 0.1% and 0.3% of soil dry weight) and four organic material levels (0, 1%, 2% and 3% of soil dry weight). Each treatment was replicated five times, giving 60 pots in total. The polyester microfibers used in the pot experiment were the same as in the field experiment. The organic materials (litter of *Populus nigra* plantation) used in the pot experiment were milled to pass through a 0.25 mm sieve. Six replicates of 110 g of air-dried soil were measured for field capacity (averaged 540 g kg^{-1} soil moisture).

At the time of pot filling in November 2017, soil fractions, polyester microfibers and organic materials were thoroughly mixed according to the pot experimental design. Then, the mixed soils were gently filled into PVC tubing (8 cm height and 15 cm diameter) to obtain a bulk density of 1.1 g cm^{-3}. The base of each pot was fixed by a porous plastic plate, and wetting was carried out from the base of the pot. All pots were placed in a greenhouse (30 ± 2 °C). Before wet-dry cycles began, all soil cores had been under a soil moisture content of 90% field capacity for 10 days to improve initial soil aggregation. Following wetting, all soil cores were naturally dried for the same drying period. When the soil moisture content was decreased to 40% of the field capacity, these soil cores were then rewetted to 90% of the field capacity. Six wet-dry cycles (between 1 and 2 weeks per wet-dry cycle) were replicated during a 75 days incubation. After each wet-dry cycle, a core (100 cm^3) of each pot was sampled to determine bulk density and porosity. At the end of the incubation (day 75), soils were sampled from each pot to determine the soil aggregate distribution.

2.3. Soil samples analysis

The soil bulk density and pore size distribution were determined using the core method (Zhang et al., 2015). The prepared cores were placed on a suction plate and then slowly wetted to saturation. During the suction measurement, the matric–potential was adjusted to −1.0 m of water. At each suction, cores were left on the suction plate until they reached equilibrium and were then weighed. The cores were oven–dried at 105 °C for 48 h or longer to reach constant weight, cooled in desiccators and then weighed. The bulk density was calculated following the methods of Cresswell and Hamilton (Cresswell and Hamilton, 2002). All the measurements were performed in triplicate for each sample.

Based on the model of parallel cylindrical tubes (Jury et al., 1991), the maximum water-filled equivalent pore diameter (30 μm) was estimated at different matric–potentials of −1.0 m. Macro–porosity of 30 μm equivalent pores was calculated from the changes in core weights (Zhang et al., 2015).

Aggregate stability in water was determined by the method of Zhang and Liu (2018). Briefly, approximately 200 g of air-dried soil was slaked in water for 5 min and then wet-sieved through a column of sieves with mesh openings of 2.00, 0.25 and 0.05 mm. To determine the stability of aggregate fractions under continuous wet conditions, the column of sieves was submerged in a cylinder of distilled water and driven up and down at a rate of 30 strokes per minute over a period of 5 mins. Four aggregate size fractions were obtained: large macroaggregates (>2 mm), small macroaggregates (2–0.25 mm), microaggregates (0.25–0.05 mm) and silt + clay fractions (<0.05 mm). The percentage of the last fraction was calculated based on the difference between whole soil and the sum of the other aggregate fractions (>2 mm + 2–0.25 mm + 0.25–0.05 mm). All measurements were performed in triplicate.

2.4. Data analysis

Prior to further analysis, normality of data from the field and pot experiments was confirmed by the Kolmogorov-Smirnov test. Analysis of variance (ANOVA) was performed to compare the data, where levels of polyester microfiber and organic amendment were fixed factors. Following ANOVA, the least significant differences (LSD) test was carried out to determine different main effects at $P < .05$. The statistical analyses were conducted using the “agricolae” package (version 1.2-4) (de Mendiburu, 2017) of R software (version 3.4.1).

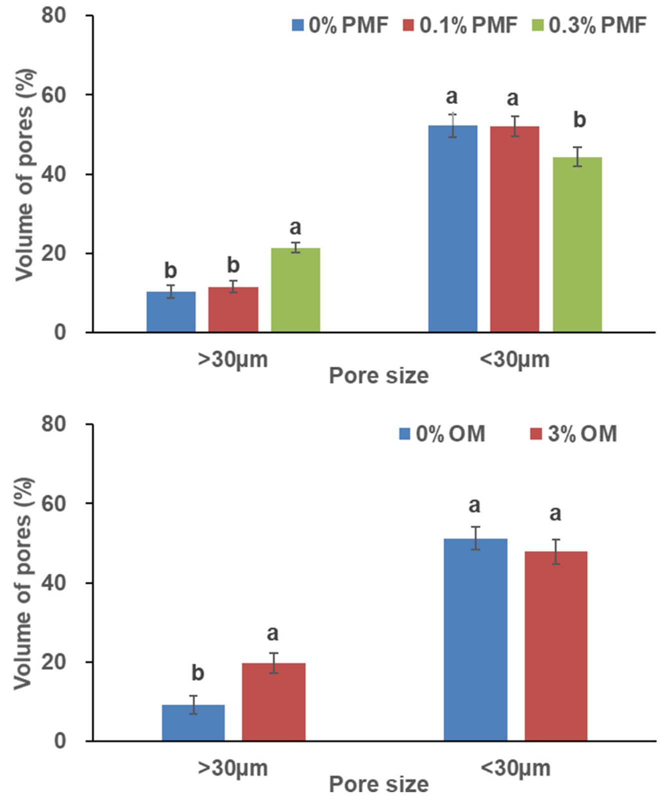

Fig. 1. Effects of polyester microfibers (top) and organic materials (bottom) on pore-size distribution in the field experiment.

3. Results

3.1. Impacts of polyester microfiber on soil bulk density, porosity, aggregation and saturated hydraulic conductivity in the field experiment

In this study, lower bulk density was observed in the organic materials added (OM) treatment (0.86 t m^{-3}) compared to the nonorganic materials added (NOM) treatment (1.05 t m^{-3}) after one year (Table 1). However, there were no detectable changes in soil bulk density among the different polyester microfiber added (PMF) treatments. A significantly higher volume of >30 μm pores in the 0.3% PMF treatment (21.4%) was observed compared to the 0.1% PMF treatment (11.6%) and the non-polyester microfiber added (NPMF) treatment (10.3%) after one year (Fig. 1). In addition, soils under the NPMF

Table 1
Effects of polyester microfibers and organic materials on soil physical properties in the field experiment after a year.

Treatments (n = 18)	Aggregate size-fractions (%)				Bulk density (t m^{-3})	K_{sat} (mm s^{-1})
	>2 mm	2–0.25 mm	0.25–0.05 mm	<0.05 mm		
0%PMF + 0%OM[a]	11.99(5.85)[b]	47.53(11.77)	34.09(8.72)	6.39(2.73)	1.06(0.04)	0.52(0.04)
0%PMF + 3%OM	29.26(14.51)	59.44(10.49)	10.00(4.24)	1.30(0.50)	0.93(0.06)	1.39(0.19)
0.1%PMF + 0%OM	10.63(3.35)	47.65(9.16)	35.87(9.22)	5.86(1.12)	1.06(0.10)	0.67(0.15)
0.1%PMF + 3%OM	32.11(6.09)	54.98(3.19)	11.18(5.69)	1.72(0.26)	0.87(0.13)	0.93(0.05)
0.3%PMF + 0%OM	6.20(2.20)	49.22(5.33)	38.93(6.91)	5.61(0.56)	1.03(0.08)	0.69(0.16)
0.3%PMF + 3%OM	26.32(8.70)	58.61(4.48)	13.58(4.23)	1.49(0.45)	0.79(0.05)	1.18(0.20)
$LSD_{0.05}$[c]	14.03	14.37	12.09	2.24	0.15	0.26

[a] Polyester microfibers (PMF); Organic materials (OM).
[b] Values in parentheses are the standard deviation.
[c] Any difference between two means in the same column larger than the $LSD_{0.05}$ value is considered a significantly different at $P < .05$.

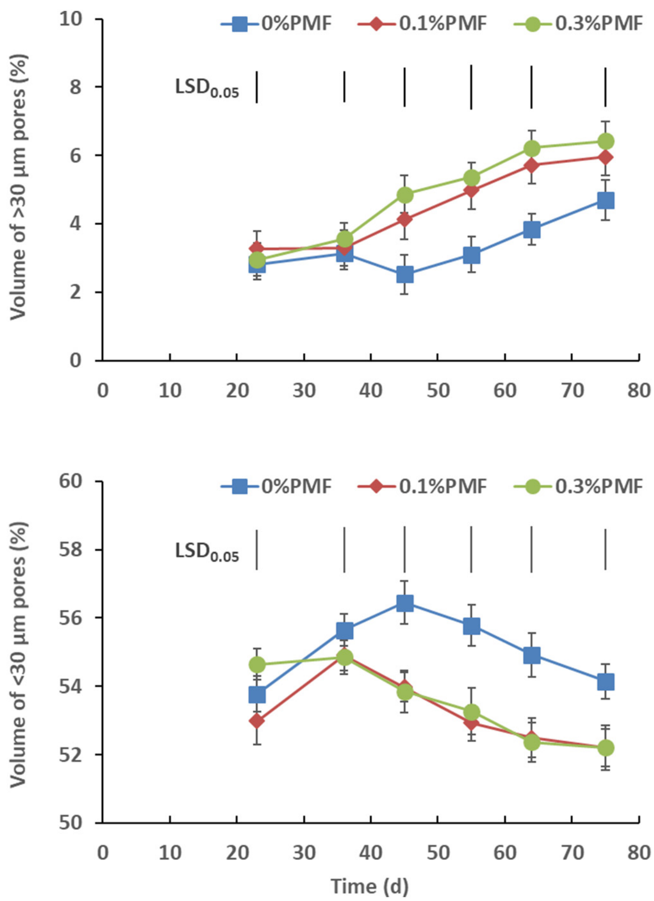

Fig. 2. Effect of wet-dry cycles on the volumes of >30 μm pores (top) and < 30 μm pores (bottom) under polyester microfibers addition treatments in the pot experiment. Any difference between two means larger than the $LSD_{0.05}$ bar is considered a significantly different at $P < .05$.

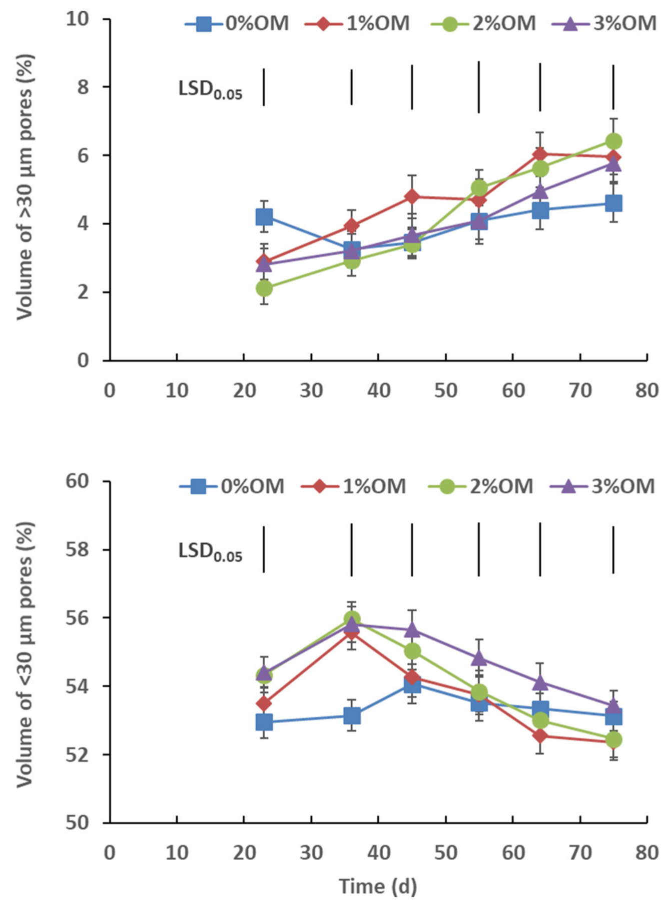

Fig. 3. Effect of wet-dry cycles on the volumes of >30 μm pores (top) and < 30 μm pores (bottom) under organic materials addition treatments in the pot experiment. Any difference between two means larger than the $LSD_{0.05}$ bar is considered a significantly different at $P < .05$.

treatment (52.2%) and the 0.1% PMF treatment (52.0%) had greater volumes of <30 μm pores than the 0.3% PMF treatment (44.4%). Furthermore, a large amount of >30 μm pores was observed in the OM treatment (19.7%) compared to the NOM treatment (9.2%) but larger volumes of <30 μm pores were not observed in the OM treatment (Fig. 1).

Similar to the bulk density, there were no detectable changes in the soil aggregate size distribution and saturated hydraulic conductivity (K_{sat}) among the different PMF treatments (Table 1). On the other hand, the large macroaggregate (>2 mm) content and K_{sat} were significantly increased in the OM treatment compared to the NOM treatment. In the field experiment, there were no significant effects of interactions between polyester microfibers and organic materials on soil physical properties.

3.2. Impacts of polyester microfiber on soil bulk density, porosity, aggregation in the pot experiment

In the pot experiment, significantly higher volumes of >30 μm pores were found in the PMF treatments compared to the NPMF treatment after two wet-dry cycles (day 36, Fig. 2). Meanwhile, drying and wetting also reduced the volumes of <30 μm pores in the PMF treatments during the first three wet-dry cycles (day 45). However, the volumes of >30 μm pores or < 30 μm pores did not differ significantly between the 0.1% and 0.3% PMF treatments during the incubation period (Fig. 2). Compared to the NOM treatment, the input of organic materials increased the volumes of >30 μm pores between day 64 and day 75, but the increase was an apparent lack of monotonicity in response to the organic material added levels (Fig. 3).

After one wet-dry cycle (day 23), significantly lower bulk densities were observed in the OM treatments compared to the NOM treatment (Fig. 4). However, there were no differences in soil bulk density between the PMF treatments and the NPMF treatment during the incubation period (Fig. 4).

After incubation (day 75), significantly higher contents of large macroaggregates (>2 mm) were found in the PMF treatments compared to the NPMF (30.8%) treatment (Fig. 5). Furthermore, the content of large macroaggregates (>2 mm) in the 0.3% PMF treatment (43.6%) was significantly higher than that in the 0.1% PMF treatment (39.3%). In contrast, the NPMF treatment had significantly higher contents of the microaggregate (0.25–0.05 mm) fraction and the silt+clay (<0.05 mm) fraction than the PMF treatments. In addition, significantly higher contents of microaggregates (0.25–0.05 mm) and silt + clay (<0.05 mm) were found in the 0.1% PMF treatment (20.3% and 4.3%, respectively) compared to the 0.3% PMF treatment (18.5% and 3.7%, respectively).

Meanwhile, drying and wetting during incubation also significantly increased the content of large macroaggregates (>2 mm) and decreased the contents of microaggregates (0.25–0.05 mm) and silt + clay (<0.05 mm) in the OM treatments compared to the NOM treatment (Fig. 5). In addition, the interaction of polyester microfibers and organic materials could also significantly increase the formation and stability of macroaggregates.

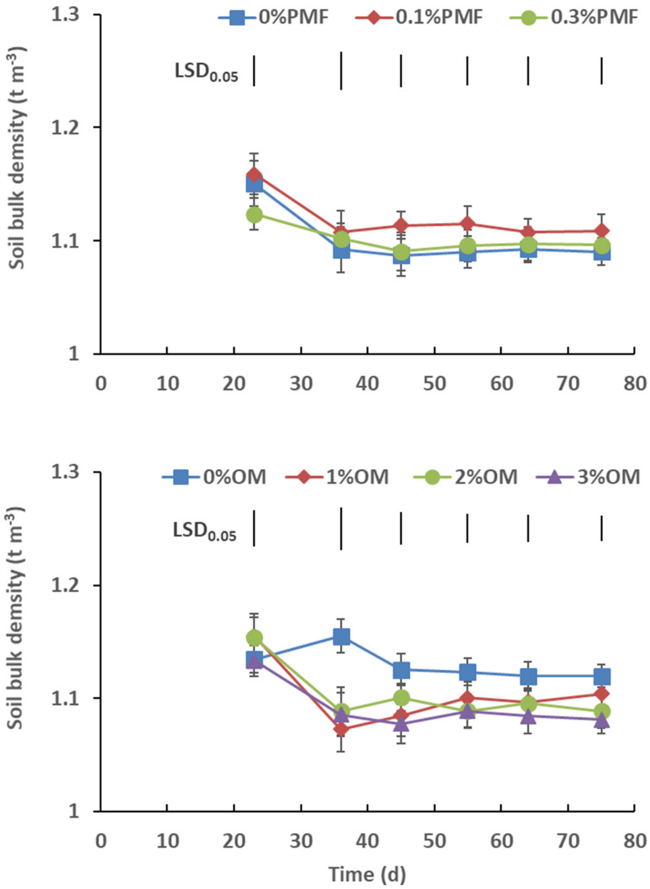

Fig. 4. Effect of wet-dry cycles on soil bulk density of polyester microfibers (top) and organic materials (bottom) addition treatments in the pot experiment. Any difference between two means larger than the $LSD_{0.05}$ bar is considered a significantly different at $P < .05$.

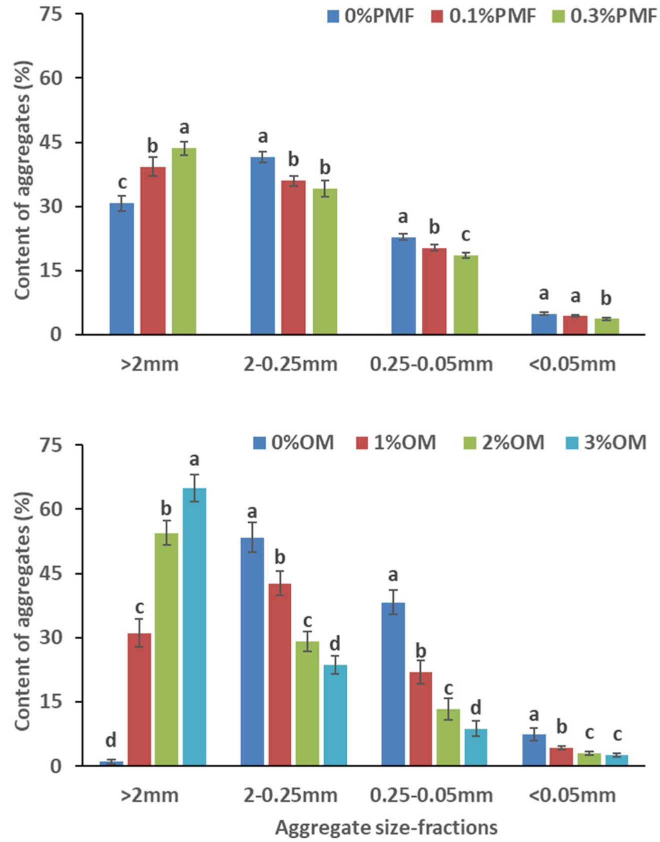

Fig. 5. Distribution of aggregate size-fractions under polyester microfibers (top) and organic materials (bottom) addition treatments in the pot experiment.

4. Discussion

The objective of the study was to assess the potential impact of polyester microfibers on the physical quality of a clayey soil. The occurrence and behavior of microplastics in soils are associated with unknown consequences for soil quality. Soil structure mediates many biological and physical processes in soils (Zhang and Ni, 2017; Gioacchini et al., 2016). Understanding the effects of microplastics on soil structure is essential to assessing the impacts of microplastics in the soil environment. Recently, some studies have reported the distribution and behavior of microplastics in soil aggregate fractions (Zhang and Liu, 2018; de Souza Machado et al., 2018). However, our knowledge on the effects of microplastics on soil structure is still limited.

4.1. Polyester microfiber effects on soil physical properties

The field and pot experiments showed that polyester microfibers cannot alter soil bulk density. This finding is not in line with a previous study reporting that polyester microfibers would decrease soil bulk density (de Souza Machado et al., 2018). The components of soil solids, such as minerals and humus, greatly influence soil bulk density. In this study, significantly lower soil bulk densities in the OM treatments were observed than in the NOM treatments due to the lower density of organic materials and their function in improving soil structure (Sollins and Gregg, 2017). However, although the polyester microfibers are also less dense than soil minerals, the very low mass (≤0.3%) of polyester microfibers should not have a substantial impact on soil bulk density in our experiments.

The pore-size distribution plays a key role in quantifying soil structure because it affects hydraulic conductivity, solute convection and water retention. The size of pores and their distribution depend on compression and the size, shape, cementing and arrangement of soil solid particles. Our results showed that the polyester microfibers significantly decreased volumes of <30 μm pores. Because the diameter of the polyester microfibers used in this experiment is <5 μm, the <30 μm pores may be easily obstructed or constricted by these tiny fibers. Additionally, due to its hydrophobic nature, polyester microfibers may induce severe water repellency in soil and then result in less water stored in these small size pores, which also leads to less volume of <30 μm pores observed by the suction plate method used in this study. Because water holding capacity is positively correlated with the volume of small pores, this result implies that ultrafine polyester microfibers can reduce the water holding capacity of soils. However, de Souza Machado et al. (2018) found that soil water holding capacity increased with increasing concentrations of polyester fiber. On the other hand, the similar volume of <30 μm pores in the OM and the NOM treatments was probably attributed to the great water absorption characteristics of soil organic matter which offset the loss of water storage space caused by organic matter in small pores.

In this study, both the addition of organic materials and polyester microfibers increased the volumes of >30 μm pores. Plowing, shrinkage, biological activity and granulation can promote the creation or enlargement of soil macropores. The addition of organic materials generally improves soil granulation, microbe activity and aggregate stability and then substantially increases the proportion of macropores in clayey soils (Angers and Caron, 1998; Yazdanpanah et al., 2016). As same, the linear shape of polyester microfibers can help them to entangle soil particles more efficiently to form clods. Therefore, the increase in clods caused by polyester microfibers can also make more soil macropores. However, similar saturated hydraulic conductivity between the PMF

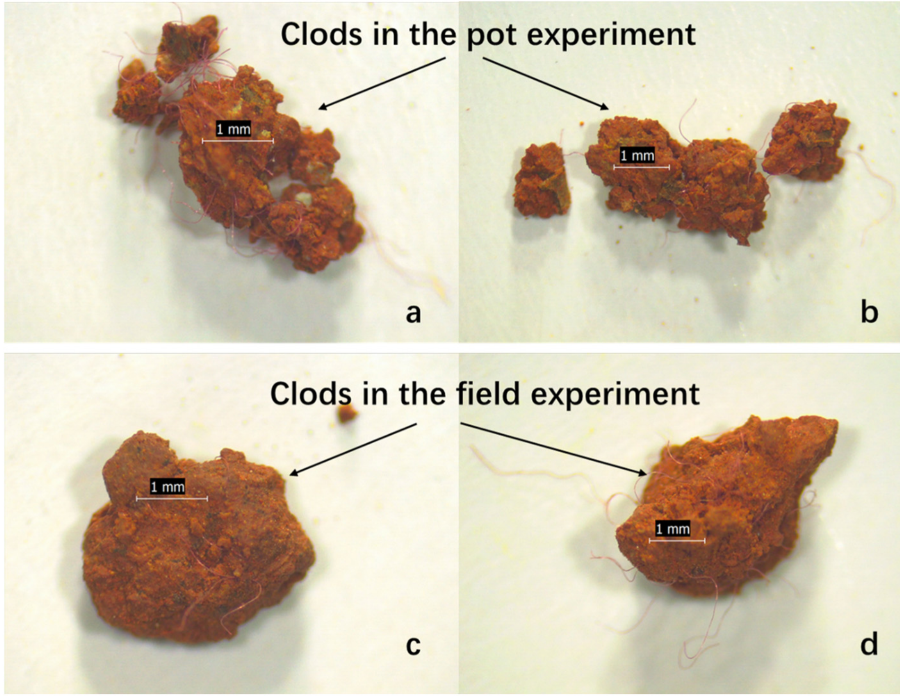

Fig. 6. The clods of polyester microfibers addition treatments in the pot experiment (a, b) and the field experiment (c, d).

and NPMF treatments implies that the macropores induced by polyester microfibers may not be as stable as those induced by organic materials.

In the pot experiment, the nonmonotonic responses of soil pore-size distribution to the addition levels of organic materials and polyester microfibers were observed. de Souza Machado et al. (2018) also observed that in responses to microplastic contamination, some of changes of soil properties was nonmonotonic. They suggested that the addition of microplastics affects soil physical, chemical, and biological processes and their interactions, with resulting nonlinear responses of soil properties.

4.2. Polyester microfiber effects on soil aggregation

The increased macroaggregate formation under the PMF treatments occurred only in the pot experiment but not in the field experiment. This may due in part to the fine soil used in the pot experiment. The soil used in the pot experiment had 40% clay and was passed through a 0.25 mm sieve, which allowed soil fine particles to more efficiently contact polyester microfibers, and then entangled with polyester microfibers to form large clods (Fig. 6 a, b). In contrast, soils in the field experiment have many clods that lot of polyester microfibers just adhere to the surface of clods (Fig. 6 c, d). The results of the pot experiment also showed significantly lower contents of the micro-aggregate fraction and the silt+clay fraction in the PMF treatments than in the control treatment.

In addition, some studies have observed that microplastics stimulate microbial and enzyme activities in soils (Liu et al., 2017; de Souza Machado et al., 2018) and increase the labile organic carbon pool (Liu et al., 2017). Soil microorganisms and labile organic carbon have profound positive influences on the formation and stabilization of soil aggregates (Tisdall and Oades, 1982; Six et al., 2004). Our results also showed that the interaction of polyester microfibers and organic materials significantly promoted soil aggregation. Finally, the frequent wet-dry cycles enhanced soil structure dynamics, which caused faster turnover of aggregates (Cosentino et al., 2006). After several drying and wetting cycles, the newly formed macroaggregates may no longer be disrupted by drying and wetting (Denef et al., 2002). Therefore, the water stability of soil clods induced by polyester microfibers was enhanced after 6 drying and wetting cycles in this pot experiment.

Our results showed that the contents of water-stable large macroaggregates (>2 mm) increased with increasing polyester microfiber concentrations in the pot experiment, which implied that polyester microfiber contamination may increase soil aggregation. However, another study found that increasing polyester concentrations significantly reduced the content of water stable aggregates in a loamy sand soil (de Souza Machado et al., 2018). Soil mineralogy and clay content are important determinants for the formation of soil aggregates (Wagner et al., 2007). In this study, the soil used here was rich in clay particles and A1/Fe-oxides/hydroxides, which may have a very high affinity for polyester microfibers. Thus, these different observations regarding the formation and stability of macro-aggregates induced by polyester microfibers are probably attributed to soil mineralogy, texture and the capability of soil particles to entangle with polyester microfibers.

On the other hand, a recent study observed a lower abundance of microplastic fibers in macroaggregates than in microaggregates and suggested that the microplastic-enriched microaggregates might not incorporate each other to form macroaggregates (Zhang and Liu, 2018). Because micron size microplastics should have more complicated behaviors than large particles, e.g., adhesivity, absorbability and mobility, the physical characteristics of soil microaggregates may be changed as micron size microplastics embed in them. The average length of polyester microfibers used in the pot experiment was approximately 2.65 mm, which resulted in polyester microfibers not easily accumulated in soil microaggregates but favored entangling with these fine particles to form large clods. Moreover, the influence of microplastics on soil aggregate size distribution is also subject to the microplastic shapes and types (de Souza Machado et al., 2018). Therefore, while the interaction of microplastics and soil fine particles is poorly understood, developing a fuller understanding of the interaction of clay (or silt) and microplastics will contribute greatly to identifying those factors that most strongly influence the structure of microplastic-contaminated soils.

5. Conclusions

Our findings indicate that polyester microfibers can alter some of physical properties of a clayey soil, e.g. pore-size distribution, aggregation. But the effects of polyester microfibers on soil bulk density and saturated hydraulic conductivity were not observed in this experiment. The different results of the soil aggregate distribution between the pot experiment and the field experiment reveal the complicated consequences of microplastic contaminated soil. The interaction of microplastics and soil mineral particles, especially fine-sized particles, could be influential when considering the potential effect of microplastics on soil structure. In addition, if the levels of microplastics in contaminated soils exceed an upper threshold, without proper monitoring, this could result in soil degradation. Therefore, further studies should focus on the effects of microplastics on soil quality and methods for monitoring the source, transport, or consequences of microplastics.

Acknowledgments

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