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Mini Review

Microplastics and Invasive Alien Plants: A Change in Soil Ecology Deliberately Impacts the Aboveground Productivity of the Crops

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ABSTRACT: Plastic is considered an emerging agroecological pollutant while biological invasion has also become a global environmental issue. Therefore, the contamination of microplastics and the occurrence of *Solidago canadensis* L. invasion in the agroecosystem may be a severe hazard to soil and plant functioning, reducing yield and perhaps indirectly harming human health. Microplastic contamination adversely affects the soil ecosystems in terms of soil carbon pools and their turnover. Invasive plants compete with agronomic crops, have allelopathic effects by secreting allelochemicals, and have detrimental effects on the productivity of the crops. However, their interaction had significant negative effects on the soil as well as the crop's physiological and biochemical properties. Thus, the interactive response created a big gap in how they raise concerns about crop potential yield and entering into the food web that ultimately affects human health.

KEYWORDS: Antioxidant enzymes, agricultural land, soil properties, biochemical interaction, yield

1. Introduction

Plastic pollution is often seen as a troubling environmental issue that has sparked global concern. Microplastics, referred to the plastic particles < 5mm, are now emerging as a challenging contaminant in soil and, more specifically, in terrestrial ecosystems worldwide (De Souza Machado et al., 2018). Based on earlier findings, researchers discovered that microplastic pollution disrupts soil physicochemical characteristics by disrupting the microorganisms present in the soil, resulting in particular toxicological consequences on terrestrial species (Rillig, 2020; Zang et al., 2020). Increased production and use in high-input agriculture result in a variety of microplastic entry routes in the terrestrial environment (Rillig, 2018; Rillig, 2020). Once microplastics reach the soil, they may be absorbed by plants through the crack-entry mechanism, resulting in negative impacts on plant growth and development (Iqbal et al., 2023a). These unfortunate results are occupied with an assortment of cycles, including diminished seed germination, diminished plant advancement, poor osmotic control, oxidative burst, decreased photosynthetic limit, and disturbance of fundamental metabolism (Iqbal et al., 2023b).

Why microplastic contamination have not been well studied along with invasive alien plants (IAP) (*Solidago canadensis* L.) on the growth, biomass, and physiological activities of the plants? Firstly, the flow of ideas from microplastic contamination in the soil,

penetration into the plant, and its influencing reaction on the growth, biomass, physiological, and metabolic activities of crops do not readily spread, and there is a significant gap in the ecological and physiological study between these. Furthermore, the microplastics and IAP were primarily associated with the changes in the physiochemical and microbiological activities of the soil, as well as the eco-physiological activities of the plants, to cope with the plant nutritional demand and increasing yield which benefitted the farmer's community. Secondly, the ideas regarding its built-in constituents and output towards the terrestrial ecosystem were not well understood. As a result, it makes it difficult for ecologists and agriculturists to take the initiative steps to stop the dispersal of microplastic contamination and protect crops from its harmful effects. Thirdly, none of the researchers focused on the emerging problems of microplastic contamination and its interactive effect with IAP on agricultural land and its solution to overcome it. However, it will diminish the soil micro-organisms due to its huge contamination and eventually make the soil unfavorable for the cultivation of crops. Fourthly, the emerging and huge contamination resulted in compacting the soil and threat to organisms, severely reducing crop production (Li et al., 2023), which is a challenging issue for food security (Figure 1). The previous researchers did not connect the microplastics and IAP with the eco-physiological activities of the crops. However, other research proved that adding some source compound to the soil will furnish and increase the same element in the soil.

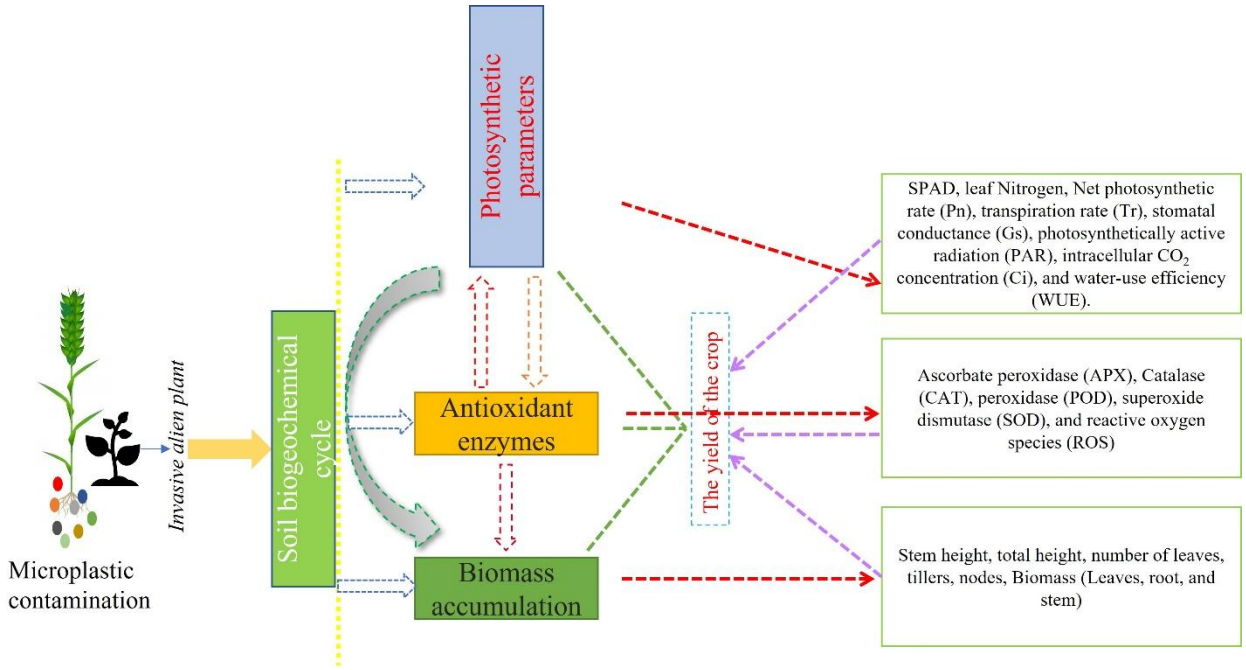

Figure 1. Descriptive representation of microplastics and invasive alien plants on soil properties and ultimately affect the plant functioning.

Thus, the addition of a large number of microplastics to our agricultural land in the form of sewage sludge, compost contamination, or plastic mulching diminished the soil properties and had a greater impact on the physiological activities of the crops. The surrounding deposition of microplastics, particularly in agricultural soil, has received a lot of attention due to a variety of factors such as eutrophication, waste-water supply, effluents addition, organic manure or agrochemicals, and the use of mulching film (Boots et al., 2019; Rillig, 2020). It is a long-lasting anthropogenic pollutant that manifests itself in different shapes and contaminates agricultural land (Chen et al., 2022). The microplastic in agricultural soil was mainly fragments rather than films or fibers and its deposition might change soil physicochemical properties (De Souza Machado et al., 2019; Feng et al., 2022) affecting plant moisture absorption and nutrient delivery to the crop root system (Zang et al., 2020). Despite these, biological invasions are frequently linked to uncontrolled growth, which causes the depletion of soil nutrients, a loss of biodiversity, and many other negative ecological impacts (Iqbal et al., 2024). The question arises of whether this increase in microplastic contamination alone or with IAP has advantageous or drastic effects on soil compaction, availability of nutrients, eco-physiological activities, and its influential effects on crop productivity. Thus, this question accomplishes and conveys a serious issue regarding the environment and its impact on crop production, which will help to develop a policy regarding the hot issue for agricultural land and food security (Figure 2).

The overproduction of reactive oxygen species (ROS) resulted in irretrievable damage to plant cells when subjected to a variety of unfavorable circumstances, including exposure to microplastics and NPs (Zhao et al., 2022). The enhanced ROS generation produced by polystyrene plastics has also been documented in various crops (Dong et al., 2020). However, the primary antioxidant enzymes are predominantly activated by polystyrene plastics (Zeb et al., 2022), and therefore these enzymes' activities are favorably associated with the concentration of microplastic (Iqbal et al., 2023a). To understand the involvement of antioxidant enzymes in the plant response to microplastic contamination, a global profile of antioxidant enzyme activity is required. Because of its effects on potential osmotic regulation, antioxidant, and metabolic profiling, and energy supply, high-efficiency carbohydrate metabolism, and phytohormones have long been thought to play a key role in the induction of plant tolerance to environmental and abiotic stress (Zeb et al., 2022). The effects of microplastics on phytohormone concentrations and their relationships to the activity of important antioxidant enzymes and carbohydrate metabolism enzymes are noteworthy because they make it easier to understand the mechanisms behind plant response to microplastics (Li et al., 2021; Iqbal et al., 2024). A key challenge will be determining whether soil surfaces can sorb microplastic particles and alternately ingest them by plants and whether they can be influential reasons alone and/or in combination with IAP for *changing* the eco-physiological activities of the plants, thereby

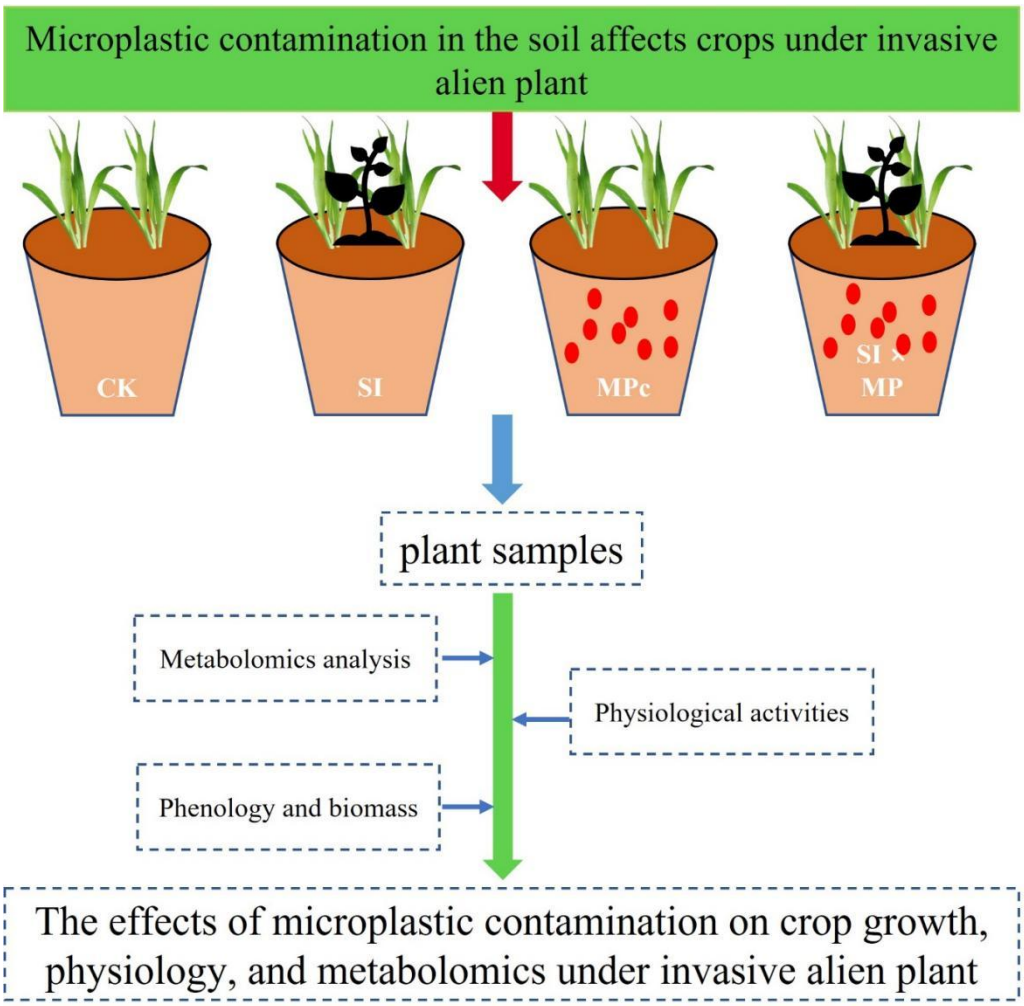

Figure 2. Overall treatment effects and their outcomes on the plants

hindering or promoting plant growth and yield.

Studying whether microplastics alone and/or in combination with IAP, due to their higher surface area and ability to exceed the plant community, restrict crop growth, and have antagonistic/synergistic effects on physiological activities and crop production, will be critical for understanding environmental implications.

Similarly, by describing a complex system of biological events, the metabolomic analysis represents the physiologic state of the plant. Modifications in metabolic activities, particularly energy metabolism, and anabolism, may interact with the defense mechanisms for the antioxidants of crops. Therefore, the variations in L-glutamine levels are mostly related to glutamate metabolism, which is frequently directly related to environmental stress since it helps remove ROS in plants (Pidatala et al., 2016). Similarly, the production of flavonoids, lignin, alkaloids, and plant antitoxins all use phenylalanine as a precursor (Liu et al., 2021). The amount of shikimic acid, crucial for the biosynthesis of secondary metabolites, was significantly reduced by the microplastic

treatment (Wu et al., 2017) and downregulated by the combined application of interactive treatments in the soil (Iqbal et al., 2024). Additionally, oxidative stress may cause the associated energy metabolism, which is dependent on the breakdown of sugar, to increase its concentration (Wu et al., 2017). Therefore, it is confirmed that the down-regulation of carbohydrates in reaction to microplastic and IAP exposure might indicate that the glycolytic pathway has been disturbed. The aminoacyl-tRNA biosynthetic pathway is also connected to the metabolic activities of cysteine and methionine, glycine, serine, threonine, valine, leucine, and isoleucine, as well as phenylalanine, tyrosine, and tryptophan. Generally, these metabolic pathways involve the metabolism of carbohydrates, lipids, and amino acids, with amino acid metabolism most affected by the interactions between microplastic and IAP (Iqbal et al., 2024).

Conclusively, the presence of microplastics in the soil is highly likely, and their influence on plant physiological activities should be thoroughly investigated, either alone or in combination with IAP, which entails the soil-plant interaction, preferably through the progressions of various enzymatic activities involved in carbohydrates metabolism and antioxidant enzymes. The microplastic particles and IAP may remain, aggregate, and finally reach levels that can alter the crop's functional biodiversity, physiological activities, growth, biomass, and yield once uptake by the plants. With microplastics and IAP interactions potentially becoming a major topic in our cities, with antagonistic/synergistic effects, for example, policymakers, regulatory organizations, and agricultural specialists may need to pay more attention to this topic to avoid yield loss and address food security concerns.

Author Contribution

The author confirms sole responsibility for the following study conception, writing, original draft, investigation; resources, writing - review & editing.

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Conflicts of interest/Competing interests

The author has no competing financial interests.

Availability of Data and Materials

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