Response of rhizosphere microenvironment to coupling of climate warming and soil pollution

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Abstract. With the development of industrialization, the pollution of heavy metals in soil, such as lead (Pb) and cadmium (Cd), has become increasingly serious. On the other hand, the century old climate warming is considered to be the result of the significant increase in the concentration of greenhouse gases, such as CO2, in the atmosphere. These changes will affect the function and stability of the terrestrial ecosystem. Therefore, in recent years, there are more and more studies on the effects of heavy metal pollution and elevated atmospheric CO2 concentration on plants. But most of them focus on the study of the aboveground part of herbaceous plants under the action of single factor, and the study of the soil microenvironment of woody plants under the combined action of these environmental factors is relatively less. This study summarized the response of rhizosphere microenvironment to the coupling of climate warming and soil pollution, in order to provide theoretical reference for improving soil quality and ecological environment.

Key word: Climate warming; Soil pollution; Rhizosphere microenvironment; Coupling effect

1. Introduction

The global warming is largely due to the increase of atmospheric CO_2, N_2O, CH_4 and other greenhouse gas emissions generated by the burning of a large number of fossil fuels. Since mankind entered the era of industrialization in the 1970s, the concentration of CO_2 in the atmosphere has been increasing year by year [1]. It is estimated that the concentration of CO_2 in the atmosphere will double by the end of the 21st century [2].The IPCC (Intergovernmental Panel on Climate Change) climate assessment report points out that the global average temperature has increased by 0.3-0.6℃ in the past 100 years [3]. By the end of this century, it is predicted that the earth's surface temperature will continue to rise by 1.4-4.8 ℃ [4], which will directly lead to climate anomalies and exacerbate natural disasters. Heavy metal pollution in soil is becoming increasingly serious in today's society [5, 6]. At present, the problem of heavy metal pollution in soil generally focuses on the pollution of significant elements such as Cd, Hg, Cr, As, Pb, among which Pb and Cd are the most prominent ones. Pure soil Pb or Cd pollution is rare, and they often exist together [7], which will pose a great threat to the safety and stability of plant rhizosphere soil ecosystem [18]. When the accumulation of heavy metals in the soil exceeds the self-purification carrying capacity of the soil, it will have a great toxic effect on aboveground plants and other soil microorganisms, which will not only reduce the quality and yield of crops, but also affect the food safety of agricultural and sideline crops through the food chain, affecting people's health [8, 9]. Both of them are major ecological issues that have become the concern of human society today, but the research on the impact of their coupling effect on soil is rare. This study will highlight the impact of their coupling on soil ecological environment, providing theoretical reference for improving soil quality and ecological environment.

2. Impact of climate warming on soil rhizosphere microenvironment

2.1 Research progress on the influence of atmospheric CO_2 on root exudates

The composition and content change of root exudates is the most direct and obvious response of plants to environmental stress. The increase of atmospheric CO_2 concentration has become the most important environmental problem facing the society today. Research shows that the increase of atmospheric CO_2 concentration affects both the aboveground parts of plants and the root environment of plants [10]. With the increase of atmospheric CO_2 concentration, the photosynthesis of plants is enhanced, and the input of organic compounds to underground roots is increased, thus stimulating the

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growth and secretion of plant roots. Because root exudates can reflect the response of plants to environmental stress and are the link between soil and plants, they have become the focus of scientific research.

According to previous studies, the increase of atmospheric CO_2 concentration can promote the secretion of amino acids and organic carbon by soil roots, further affect the quantity and activity of rhizosphere soil microorganisms, and promote the symbiosis between plant roots and mycorrhizal fungi, resulting in significant changes in plant rhizosphere soil microenvironment. The changes in the number and morphology of roots with the increase of atmospheric CO_2 concentration may help plants to absorb more nutrients and water under environmental stress, so as to better adapt to the environment after the increase of atmospheric CO_2 concentration.

2.2 Research progress on the impact of atmospheric CO_2 on soil microorganisms

In recent years, the increase of atmospheric CO_2 concentration has become a global environmental problem, which will inevitably affect soil microorganisms. The increase of atmospheric CO_2 concentration mainly affects plant growth and indirectly affects soil microbial activity [11]. The increase of atmospheric CO_2 has different effects on soil microbial community structure, metabolic activity, microbial flora and activity [12]. The increase of atmospheric CO_2 concentration can stimulate microbial activity to a certain extent, and microbial population, quantity, composition and activity change with environmental change. Among them, the number of living cells of microorganisms is the most sensitive biological indicator to environmental change.

Although there are more and more studies on the response of soil microbial biomass and microbial population to atmospheric CO_2, most of the studies are still focused on the impact of a single environmental factor on microorganisms, and there are still few reports on the interaction conditions between the increase of atmospheric CO_2 and the combined pollution of heavy metals in soil. The response of soil microorganisms to environmental changes is a very important link in the process of ecosystem feedback, and is the key to comprehensively evaluate the impact of environmental changes on terrestrial ecosystems, which needs further research.

2.3 Research progress on the effect of atmospheric CO_2 on soil enzyme activity

Soil enzymes are biologically active proteins in soil. Through the biochemical transformation of a variety of organic substances and organic residues entering the soil, the components of the ecosystem are functionally linked, thus maintaining the relative stability of soil biochemistry, which can be used as one of the indicators of soil fertility. In recent years, the impact of elevated atmospheric CO_2 concentration on soil enzyme activity has attracted extensive attention of researchers. The final research results usually show significant promotion, but there are also different conclusions. In general, the increase of atmospheric CO_2 concentration increases the number and activity of most enzymes, but the experimental results are often different due to different research methods, research time, research environment and enzyme types.

3. Impact of soil pollution on soil rhizosphere microenvironment

3.1 Research progress on the effect of heavy metals on root exudates

Plant roots play a very important role in the biosphere biosphere interface. When the soil environment changes or is stressed, roots will actively release specific secretions. Root secretions change the bioavailability of heavy metals by changing the pH value of rhizosphere soil and chelation, thereby affecting the absorption of heavy metals at the root interface and reducing the toxicity of heavy metals to plant roots.

Under the combined action of Pb, Cd and Cd/Pb, the types of root exudates change to varying degrees, which is mainly related to the complexation reaction between root exudates and heavy metals. The complexation ability is related to the nature of heavy metals themselves. The complexation ability of wheat root exudates to Pb is greater than that of Cd. When wheat plants are polluted by Pb, Cd and Cd/Pb, the amount of sugar secreted by wheat roots increases, and tartaric acid is newly added in root exudates. Citric acid is only detected in root exudates polluted by Cd and Cd/Pb, indicating that heavy metals will have an impact on wheat root exudates in terms of both species and quality.

3.2 Research progress on the effects of heavy metals on rhizosphere soil microorganisms

Soil microorganisms are the most active members in the terrestrial ecosystem, and also the important driving force and main participants in the decomposition of soil organic matter and the transformation and circulation of soil nutrients. They promote the material cycle and energy flow of the ecosystem and maintain the normal operation of the ecosystem. The species, quantity, distribution and community composition of rhizosphere soil microorganisms are affected by soil nutrient status, pH, texture, temperature, humidity and aeration. Soil microorganisms need energy and nutrients in their life activities, so any factors affecting the soil environment will have an impact on soil microorganisms to a certain extent.

In recent years, the pollution of heavy metals in soil has become more and more serious, which inevitably changes the living environment of soil microorganisms, thus affecting soil microorganisms in varying degrees. The influence of heavy metal pollution on soil microorganisms is related to its species and concentration, soil physical and chemical properties, and single or combined heavy metal pollution. Heavy metal ions in the environment can form coordination complexes or chelates with various organic polymers and anions, which are easily adsorbed on the surface of minerals and organic substances and accumulated in sediments, thus affecting

the bioavailability of heavy metals in soil, and also having a significant negative impact on soil microbial biomass and activity, thereby affecting the stability of soil ecological structure and function.

3.3 Research progress of heavy metal pollution on soil enzyme activity

Heavy metals can interact strongly with proteins and various enzymes in the soil, so that their biological effects are inhibited and inactivated, and they can also be enriched in the soil. If the ion level of heavy metals reaches or exceeds the physiological limit that plants can tolerate, it will cause toxic effects. Soil enzymes are sensitive to the toxicity of heavy metal ions, and the determination of soil enzyme activity is helpful to determine the degree of heavy metal pollution in soil and the ability of plants to repair contaminated soil [13].

In many cases, soil enzyme activity will decrease with the aggravation of soil heavy metal pollution. Under the stress of heavy metals, the molecular structure of soil enzymes is destroyed, leading to the inactivation of enzymes. However, when the content is low and does not reach the level of pollution, it will activate soil enzymes. This is mainly because they promote the coordination and binding of enzyme molecules with the substrate, thus enhancing the enzyme activity.

4. Response of rhizosphere microenvironment to coupling of climate warming and soil pollution

Soil microorganism is a biological indicator of soil health, which has an important impact on soil fertility. The growth and activity of soil microorganisms are affected by environmental conditions such as soil pH, humidity, temperature, external interference, etc., which can sensitively indicate changes in climate and soil environmental conditions. Therefore, human industrial and agricultural development activities inevitably change the living environment conditions of soil microorganisms. The results of this study showed that the increase of atmospheric CO_2 concentration and the coupling of soil Cd/Pb pollution had a significant impact on the microbial activity of plant rhizosphere soil. Soil microbial activity is very sensitive to atmospheric CO_2 concentration, and the increase of atmospheric CO_2 concentration has a positive effect on the activity of bacteria, fungi, actinomycetes, microbial biomass C, microbial quotient and total microorganisms.

This may be due to the increase of atmospheric CO_2 concentration will bring more organic substrates to rhizosphere microbial metabolism, thus stimulating rhizosphere microbial activity and improving microbial activity. Under Cd or Pb stress, bacteria, actinomycetes, microbial biomass C, microbial quotient and total microbial activity were inhibited. The inhibition increased with the increase of Cd concentration, but the number of fungi did not change significantly, which may be due to the lower sensitivity of fungi to heavy metals than bacteria and actinomycetes. Root exudates interact with rhizosphere soil microorganisms. Root exudates are an important medium to connect plants and root soil microorganisms. Changes in plant root exudates can affect the activities of microorganisms. Root exudates a large amount of sugars, amino acids and other organic substances provide important nutrients and energy materials for the growth and reproduction of plant rhizosphere soil microorganisms, enabling microorganisms to multiply in large quantities.

5. Conclusion

(1) The increase of atmospheric CO_2 concentration promoted the total soluble sugar, amino acids, organic acids and total phenolic acids secreted by roots of Robinia pseudoacacia seedlings. Under Cd/Pb compound condition, the stimulation of Robinia pseudoacacia root system was enhanced. Compared with the effect of Cd alone, the content of total soluble sugar, amino acid and organic acid increased significantly, while the content of total phenolic acid decreased. Under the coupling of high concentration of atmospheric CO_2 and soil Pb and Cd pollution, the content of total soluble sugar, amino acid, organic acid and total phenolic acid secreted by plant roots is higher than that of heavy metals or CO_2 alone.

(2) Compared with the effect of Cd or Pb alone, the soil enzyme activity under Cd/Pb combined pollution decreased, indicating that the toxic effect of combined pollution on soil biological activity was enhanced. Soil urease activity, dehydrogenase activity β The activities of glucosidase and invertase were significantly higher than those of Cd, Pb and Cd/Pb alone, indicating that high concentration of atmospheric CO_2 could reduce the inhibition of heavy metals on soil enzymes.

(3) At the same Cd, Pb and Cd/Pb pollution levels, compared with the atmospheric CO_2 concentration, the increase of CO_2 concentration significantly increased the number of bacteria, fungi and actinomycetes in the rhizosphere soil of Robinia pseudoacacia seedlings, and the microbial biomass C, microbial quotient and total microbial activity also gradually increased. CO_2 has a certain role in promoting the survival and development of soil microorganisms. On the whole, the increase of atmospheric CO_2 concentration can mitigate the adverse effect of soil Cd and Pb pollution on plant rhizosphere soil microecology.

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