ISSN: 2710-0588

The Response of Plants to Soil Pb Stress

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Abstract

The problem of soil heavy metal pollution is becoming increasingly serious, and Pb is one of the main causes of soil heavy metal pollution due to its toxicity. Phytoremediation technology can reduce the content of heavy metal pollutants and improve soil nutrient conditions, and thus, it is more widely used. Pb in the soil affects the physiological and biochemical processes of plants, which in turn have a toxic effect on plants, causing severe wilting and death. Similarly, Pb also affects plant photosynthesis to varying degrees. This paper details the progress of research on the effects of soil Pb contamination on plants, with the aim of finding directions for further study.

Keywords

Soil Contamination; Toxic Effect; Physiological and Biochemical Functions.

1. Introduction

Heavy metal contamination of soil is one of the environmental problems of global concern, and Pb is one of the most toxic heavy metal persistent pollutants, which is the main cause of environmental contamination [1]. Pb is a kind of toxic heavy metal which is very harmful to human body, and it is also one of the five heavy metals which are included in China's "14th Five-Year Plan for Ecological and Environmental Protection", which focuses on monitoring and controlling the emission of pollutants. According to the results of the national survey on the status of soil pollution released in April 2014, soil Pb pollution around non-ferrous metal mining areas was more serious, with a point exceedance rate of 1.5% [2]. Shaanxi Province is located in the inland hinterland of Northwest China, which is an arid and semi-arid region, and the Qinling Mountain area is rich in mineral resources, of which Pb mineral reserves rank among the top 12 provinces in the west. Activities such as industrial and mining exploitation and smelting have led to the rapid spread of Pb pollution, and the problem of soil Pb contamination in areas surrounding industrial and mining areas has become increasingly prominent.

2. Remediation Methods

Compared with other remediation methods, phytoremediation technology is not only able to stabilise the structure of the surface soil layer and reduce the geological disasters caused by mining activities, but also has the advantages of improving the soil nutrient conditions, reducing the content of heavy metal pollutants, and realising the advantages of pollution remediation and ecological restoration at the same time, so the application of phytoremediation technology to remediate the heavy metal pollution of the industrial and mining areas is more

ISSN: 2710-0588

widely used. The phytoremediation research on heavy metal Pb pollution was carried out earlier in foreign countries, mainly focusing on screening Pb hyper-enriched plants, and more than 500 kinds of Pb hyper-enriched plants were found, including Curbitaceae and Blue Cloud Ying, etc.; the cumulative effect of plants on heavy metal Pb was investigated [3], and differences in the cumulative effect of plant tissues and organs on Pb were revealed [4].

Since Pb is not an essential element for plant growth and development, its accumulation in the plant can affect the absorption and stability of nutrients, be toxic to the plant, interfere with normal growth and physiological metabolic processes, and impair morphological, physiological, and biochemical functions. Pb affects many morphological, physiological, and biochemical processes in plants [5]. Growth parameters such as root length, above ground part fresh weight and dry weight of plants are generally reduced due to Pb stress. Hattab et al [6] found that alfalfa treated with Pb at a concentration of 33.1 mg/L for 7 days, shoot fresh weight and length would be lower by 41% and 44%, respectively, as compared to untreated group; and root fresh weight and length were reduced by 48% and 31%, respectively. Venkatachalam et al [7] reported that with the increase in Pb concentration, indica rice showed a significant reduction in root length, shoot length, plant fresh weight and dry weight. In addition to these growth parameters, plant height, plant yield, leaf area, number of leaves, leaf length and leaf width, which are critical for plant growth, were also affected by Pb stress.

3. Photosynthesis

Photosynthesis is the basis of all food chains in an ecosystem, and when Pb is taken up by plants, photosynthesis is affected to varying degrees. Heavy metal Pb enters into the plant cells by altering the content of phytochromes, which are dominated by photosynthetic pigments. The most basic phenotypes of Pb-induced triggered phytotoxicity are wilting and yellowing of leaves, inhibition of growth and development, weakening of the strength of photosynthesis, closure of stomata, decrease in leaf transpiration rate, and deposition of photosynthesis-related pigments, such as chlorophylls and carotenoids [8]. Chlorophyll (Chl) mainly contains chlorophyll a (Chl a) and chlorophyll b (Chl b), etc., of which Chl a is one of the most important pigments in photosynthesis, and Chl b helps in the absorption of light energy by the plant, but it is more easily degraded than Chl a. Usually the effect of Pb on Chl a is greater in leaf tissues [9]. However, Pb in plant tissues is not toxic to all pigments and a positive response of Chl pigment concentration to Pb has also been observed in few studies. Pigments such as carotenoids may also be affected by Pb. Carotenoids provide plants with pigments that play an important role in protecting Chl molecules from intense light exposure and are also non-enzymatic but antioxidant active and free radical scavenging substances that have the potential to protect plants against oxidative stress [10]. It has also been pointed out that Pb-induced changes in parameters related to plant growth and development and inhibition of physiological and biochemical responses may be related to Pb-mediated alterations in plant tissue structure, reduced nutrient metabolism, weakened photosynthesis, and disruption of water transport systems. The ratio of Chl a, Chl b, total Chl and carotenoid content appeared to be reduced in both cotton leaves and ryegrass leaves after certain concentrations of Pb^{2+} stress [11]. However, it has also been shown that different concentrations of Pb did not significantly affect lettuce growth parameters, which may be due to different plant species [12].

4. Problems

Previous studies have shown that plantain (Plantagoasiatica L.) can grow under Pb stress and exhibit low toxicity symptoms [13], as well as having the advantages of a wide range of species suitability and soil adaptability, which can be regarded as a potential plant for remediation of Pb-contaminated soil. Currently, there are fewer studies on the tolerance and accumulation of

ISSN: 2710-0588

Pb in plantain. Therefore, taking the typical pollutant element Pb as the research object, we investigated the interaction between Pb pollution stress and plant growth and metabolism by determining the physiological and biochemical indexes of Plantago ovata under the conditions of different soil Pb contents.

Acknowledgments

This paper was funded by the Research project of Shaanxi Provincial Land Engineering Construction Group in China (DJNY-YB-2023-29).

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