Studies of Phytoremediation on Sasa argenteastriatus for Soil Cadmium Pollution

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Abstract. In order to explore the Phytoremediation effect of \textit{Sasa argenteastriatus} on cadmium-contaminated soil, pot experiments were conducted to study the growth and enrichment efficiency of \textit{Sasa argenteastriatus} on cadmium-contaminated soil. The results showed that cadmium had a significant inhibitory effect on the growth of \textit{Sasa argenteastriatus}, and the inhibitory effect increased with the increase of cadmium concentration. Cadmium content in roots, stems and leaves of \textit{Sasa argenteastriatus} increased with the increase of exogenous cadmium, especially in roots. The order of cadmium enrichment efficiency was the same in different cadmium contaminated soils, all of them were leaves < stems < roots. And the cadmium enrichment coefficient in root was obviously higher than that in other organs. The research on growth and enrichment of \textit{Sasa argenteastriatus} under cadmium stress provides theoretical basis and data support for its application in cadmium-contaminated areas.

1. Introduction
Soil heavy metal pollution is a global problem and has become a hot research topic. Heavy metal cadmium (Cd) mainly comes from industrial "three wastes" and chemical fertilizers, pesticides and sewage irrigation and other factors [2]. Cd is a non-essential growth element of crops, which is easily absorbed and enriched by crops in the soil, and ultimately endangers human health through the food chain.

Phytoremediation refers to the technology of reducing or removing heavy metal pollutants in soil by utilizing some special physiological functions of plants (such as absorption, degradation, stabilization and volatilization) [3]. Phytoremediation efficiency depends on the content of heavy metals in soil and the biomass of plants. However, a large number of phytoremediation studies on cadmium-contaminated soil are focused on herbaceous plants (such as Bidens pilosa, rye, etc.). Herbs have some defects such as short plant, slow growth and long repair time, and their economic value and ornamental value are not high. Although woody plants have large biomass, well-developed roots and can accumulate a large amount of heavy metals, it is difficult to transplant and the growth cycle is slow, so the research is also in a slow stage. Therefore, it is particularly important to find a plant for remediation of cadmium-contaminated soil with fast growth, high biomass and high ornamental economic value.
Sasa argenteastriatus is a kind of ground cover bamboo, belonging to Gramineae Pleioblastus. It originated in Japan, was introduced to Nanjing and Zhejiang in 1995, and introduced to Sichuan in 2006 [4]. Sasa argenteastriatus has the characteristics of rapid root propagation, strong coverage, large biomass, rapid growth and extensive maintenance. At present, there are few studies on Sasa argenteastriatus in China. Wang et al. reported the resistance of Sasa argenteastriatus to drought, salt and low temperature stress [5]. Liu et al. studied its root distribution characteristics [6]. Little research has been done on the remediation of heavy metal contaminated soil by Sasa argenteastriatus, which greatly limits the application and theoretical research progress of Sasa argenteastriatus in soil contaminated areas. Therefore, it is of great value and practical significance to carry out the study of Sasa argenteastriatus on contaminated soil.

2. Materials and methods

2.1. Study materials
Sasa argenteastriatus comes from Chezi Town, Leshan City, Sichuan Province, China. The tested soil is yellow cinnamon soil. The background value of cadmium is 0.01 mg/kg.

2.2. Study methods
The experiment was carried out in the greenhouse in Leshan. The experiment was carried out in a plastic basin of 43.5 cm *20 cm *14.5 cm (plastic trays were placed under the basin to prevent cadmium leakage). 5 kg of dry soil was filled in the basin. Cd (NO3)2 was used to allocate 5 gradients of Cd (0 mg/kg, 2 mg/kg, 5 mg/kg, 20 mg/kg and 50 mg/kg) (in terms of soil dry mass). Each treatment was repeated nine times.

The gradient of pollution is set according to China’s GB15618-1995 "Standard for Soil Environmental Quality", that is, the soil Cd content (>1mg/kg) belongs to contaminated soil, and refers to the background value of farmland soil in Sichuan. After two weeks, two Sasa argenteastriatus with similar age and biomass were selected for planting in a basin. Three plants were randomly selected from each treatment after 2 months to determine the cadmium content in the root, stem and leaf parts of Sasa argenteastriatus, and the cadmium enrichment factor were calculated (Enrichment factor = Cd content in plant organs/total Cd content in soil).

2.3. Determination method
The cadmium content was determined by HNO3-H2O2 digestion- atomic absorption spectrometry.

2.4. Statistical Analysis
The results were analyzed by one-way ANOVA and P<0.05 was considered to be significant.

3. Results and Analysis

3.1. Soil Cd content
The content of Cd increased obviously with the increase of Cd addition. The content of Cd in soil increased rapidly when adding 5 mg/kg-50 mg/kg exogenous Cd. When the addition of exogenous Cd reached 50mg/kg, the content of cadmium in soil was the largest, reaching nearly 20mg/kg.
3.2. *Sasa argenteastriatus* biomass
Cd obviously inhibited the growth of the *Sasa argenteastriatus*, and the inhibition increased with the increase of Cd concentration. In the 20-50mg/kg Cd addition, the underground biomass and aboveground biomass of *Sasa argenteastriatus* decreased sharply. The underground biomass of the *Sasa argenteastriatus* decreased 36% compared with that of CK when the 50mg/kg Cd was added. It showed that high concentration of Cd has a strong toxic effect on *Sasa argenteastriatus*. When exogenous Cd was added 2-5mg/kg, the biomass of the *Sasa argenteastriatus* leaves increased slightly, and the leaf weight per plant increased 0.4-0.6g compared with the control.

3.3. *Characteristics of Cd concentration in all parts of Sasa argenteastriatus*
The Cd contents in the roots, stems and leaves of *Sasa argenteastriatus* increased with the increase of exogenous Cd addition in the soil, especially in the roots. When exogenous cadmium was added to 50 mg/kg, the highest content of cadmium was found in the root, which was 8.61 mg / kg, significantly higher than that in the control (P = 0.000).

In the fig.3, the difference of concentration curve between roots, stems and leaves is large. The highest cadmium content was found in roots, followed by stems, and the lowest in leaves. The results of statistical analysis showed that, when exogenous cadmium was added in the range of 20-50mg/kg, the content of cadmium in stems and leaves of *Sasa argenteastriatus* was significantly higher than that in control and low exogenous cadmium addition (P < 0.01).
Fig. 3 Cd content in roots, stems and leaves of *Sasa argentea*striatus under different concentration gradients of Cd pollution

3.4. *Cd enrichment efficiency of all organs of Sasa argentea*striatus

It can be seen from table 1 that in different degrees of Cd polluted soil, the order of cadmium enrichment efficiency of all organs of *Sasa argentea*striatus is the same, which is leaf < stem < root, and the cadmium enrichment coefficient of root is significantly higher than that of other organs, indicating that the degree of cadmium pollution has little influence on the enrichment efficiency of cadmium in all organs. The cadmium absorption of *Sasa argentea*striatus is mainly concentrated in the root, and then gradually transported to the stem and leaf. The Cd concentration coefficients of *Sasa argentea*striatus in low cadmium polluted soil was significantly lower than that in high cadmium polluted soil. The average values of Cd concentration coefficients of roots, stems and leaves in the control group were 89.67%, 89.79% and 80.53% lower than those in the 50mg/kg Cd addition group, respectively. The results showed that the concentration of cadmium in soil had a significant effect on the cadmium enrichment efficiency of all organs. It showed that the Cd enrichment efficiency of each organ increased significantly with the increase of Cd concentration in the polluted soil.

| Cd pollution | root       | stem       | leaf       |
|--------------|------------|------------|------------|
| CK           | 0.00336466 | 0.00015312 | 0.00018416 |
| T1           | 0.005065405| 8.80425E-05| 0.000126108|
| T2           | 0.00656775 | 0.00019221 | 0.00013863 |
| T3           | 0.02838354 | 0.00042455 | 0.00056441 |
| T4           | 0.03255616 | 0.001499706| 0.000946   |

**Table 1. Difference of Cd enrichment coefficient in different organs of Sasa argentea*striatus**

4. Discussion

Cadmium is a nonessential element of plants. The higher content of cadmium in soil will reduce the photosynthesis of plants, interfere with the redistribution and migration of nutrients in plants, and affect the growth of plants. When the content of cadmium in soil is low, it can promote the growth and development of some plants, and the biomass of plants will increase. The results of this study show that the low concentration of cadmium stress increases the biomass of *Sasa argentea*striatus leaves, and also confirms the phenomenon of "low promotion and high inhibition" of cadmium on plants [8].

The difference of cadmium accumulation in plants mainly depends on two aspects. One is the genetic characteristics of plants, such as the efficiency difference and adaptation mechanism of cadmium absorption, accumulation and transport in roots. Second, environmental factors, such as the change of cadmium concentration, pH and cadmium form in soil, will lead to the change of cadmium availability and metabolism mechanism in soil, and then lead to the difference of cadmium accumulation and transfer in various organs of plants [9].
In this study, the highest cadmium content was found in roots, the second in stems and the lowest in leaves, which was consistent with the rule of heavy metals accumulation in most plants. The accumulation and transport of heavy metal cadmium in soil-plant are restricted by many factors. Root is the main organ for plant to absorb and accumulate cadmium, so the cadmium absorption capacity of plant root directly affects the above ground transport capacity [10-12]. In this study, cadmium is mainly concentrated in the root system, indicating that the transport capacity of cadmium is poor at all concentration levels, and the upward transport capacity is weak. The results showed that the tolerance and storage mechanism of Cd were mainly absorbed in roots and reduced the transport to stems and leaves, so as to reduce the harm of Cd. Some studies have found that the cadmium in the plant body is about 49% - 79% in the root [13]. In this study, more than 90% of the total cadmium absorbed by the *Sasa argenteastriatus* is concentrated in the root, and the cadmium transport capacity in the root-stem is very little, so that the cadmium content in the final transport to the leaves is less. According to the definition of hyperaccumulator, under the condition of this study, the absorption of Cd by *Sasa argenteastriatus* is not up to the standard of hyperaccumulator, but its biomass is larger than that of other herbs, and the aboveground part is tall and easy to harvest, which is worth paying attention to and a potential advantage.

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