Advances in Engineering Research, volume 170
7th International Conference on Energy and Environmental Protection (ICEEP 2018)

Tolerance Characteristics of *Sonchus arvensis L.* on Cadmium

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Keywords: *Sonchus arvensis L.*; MDA; POD; CAT; SOD; Cadmium; Biomass; Chlorophyll

Abstract. In this paper, using artificial controlled pot experiment to treat *Sonchus arvensis L.* with different concentrations of cadmium (Cd), the tolerance of Cd in *S. arvensis* was studied, and the results showed that with the increase of Cd concentration, biomass rises first and then falls, the chlorophyll showed a downward trend,SOD, POD and CAT three enzyme activities were increased first and then decreased. MDA has a certain increase. When the Cd concentration was 0.5mg/ kg, the biomass reached the maximum value, the increase was about 10.17% compared with the contrast group, and there was no significant difference in chlorophyll content compared with contrast in the low concentration Cd treatment (P<0.05). When the Cd concentration was 1.0mg/kg, SOD, POD and CAT showed higher activity. Compared with the control, SOD activity increased by 12.99%, POD activity increased by 80.39%, and MDA content did not increase, and significant reduced by 15.11%. It indicated that *S. arvensis* has strong tolerance to Cd pollution, and *S. arvensis* has certain potential application value in repairing Cd contaminated soil.

Introduction

In recent years, with the continuous development of the economy, human activities have caused serious heavy metal pollution to the soil. Contaminants containing heavy metals have entered the soil in different forms and ways, so that the heavy metal content in the soil is much higher than that of the threshold value [1]. Among them, cadmium (Cd) is a typical heavy metal pollutant, which has a wide area in China. Phytoremediation is an economical and convenient method of soil remediation. Plants easily absorb heavy metal Cd in soil, but cause serious toxic damage to their bodies [2]. Therefore, it is necessary to understand the tolerance mechanism of plants to heavy metals to ensure the long-term and effectiveness of plants to repair soil.

Malondialdehyde (MDA) content is a very important physiological indicator to measure the degree of membrane lipid peroxidation, which is the degree of damage to plants caused by heavy metals [3]. Peroxidase (POD), Superoxide Dismutase (SOD) and Catalase (CAT) play an important role in scavenging free radicals produced by heavy metal stress and protecting cells from damage [4,5] .

S. arvensis is a perennial herb, widely distributed throughout the country. It is extremely adaptable. In addition, *S. arvensis* also has good medicinal health value [6]. In terms of heavy metal repair, Qingling Zhao et al [7] found that *S. arvensis* is significantly enriched in mercury. Zheng Fan et al. [8] also confirmed that *S. arvensis* is a mercury-enriched plant through simulation experiments. At present, there are few studies on the application of *S. arvensis* in the repair of other heavy metal pollutants, especially the research on the tolerance of soil heavy metal Cd pollution has not been reported. In order to find out whether *S. arvensis* can become a soil-remediation plant enriched with heavy metal Cd. In this experiment, the Cd-contaminated pot experiment was conducted to study the effects of Cd on MDA, POD, SOD and CAT in *S. arvensis*. The law aims to grasp the tolerance characteristics of *S. arvensis* to Cd, and provide reference and theoretical basis for subsequent research.

Materials and Methods

Experimental Material. Seeds of *S. arvensis* are purchased at the market. The soil is the sandy loam form Wenjiang Campus of Sichuan Agricultural University. The basic physical and chemical properties and the background value of heavy metal content are shown in Table 1. The heavy metal in the contaminated soil is analytically pure (AR) $Cd(NO_3)_2.4H_2O$. The plastic basin is purchased from the company of Vanke, and the specification is 30cm×25cm (diameter×height), and the model is AC320.

Table 1 Basic properties of experimental soil

Item	pH	Organic matter (g /kg)	Alkaline nitrogen (g /kg)	Effective phosphorus (g /kg)	Available potassium (g /kg)	CEC (cmol /kg)	total cadmium background (g /kg)
Content	6.8	11.8	22.7	20.1	16.1	18.5	0.28

Experimental Design. According to the National Standard of the People's Republic of China, Soil Environmental Quality Standard (GB15618-1995), the simulated contaminated soil is divided into three categories: Class II soil, Class III soil, and much larger than Class III soil. According to the preset concentration, Cd(NO3)2.4H2O is completely dissolved in deionized water to a specific concentration, then uniformly applied to each pot of dried soil. Divided into five different Cd concentrations, each concentration is a group, and each group is set to 3 pots. The experiment has a total of 15 pots, 3 plants per pot, a total of 45 plants. The concentrations of the Cd group were 0, 0.5, 1, 1.5, and 2.0 mg/kg, respectively. The remaining indicators were consistent in each pot except for the heavy metal content in the soil.

Then, 0.1kg of *S. arvensis* seeds were selected and dried for 2 days, then soaked in water for 10 hours. Finally, the seeds are soaked with 0.1-1% hydrogen peroxide for disinfected, and soaked for about 5 hours to promote seed germination. The germination method of the common petri dish is used, and the germination and seedling culture are placed in the incubator.

Seedlings of similar shape were selected and transplanted into plastic pots with contaminated soil, and 3 seedlings were transplanted per pot for 60 days.

After 60 days of cultivation, the mature *S. arvensis* was harvested. When sampling, rinse the top part of the plant with distilled water and store it in an ultra-low temperature freezer (DW-60W100). Finally, the aerial parts of the plants collected were measured according to the various methods in Table 2 below.

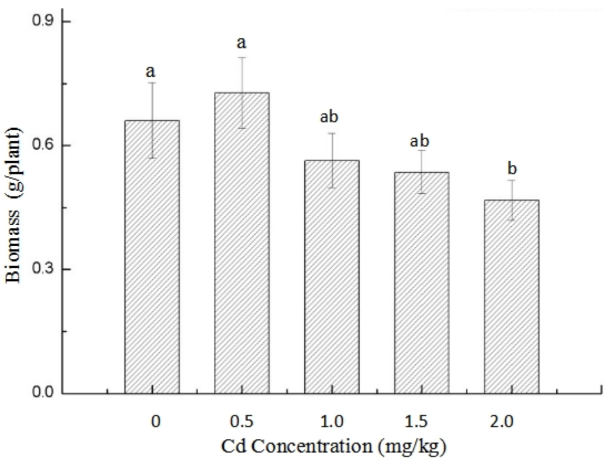
Table 2 Determination indexes and methods for the study of cadmium tolerance characteristics

Measurement index	Biomass	Chlorophyll content	MDA content	SOD activity	POD activity	CAT activity
Experimental methods	Drying-weighing method[9]	Spectroph-otometry[10]	Thiobarbituric acid ,TBA[11]	NBT Reduction method[12]	Guaiacol colorimetric method[12]	Potassium [12]

Statistical Analyses. The table was drawn with Microsoft Excel software, the SPSS20.0 was used for statistical analysis, and the graph was produced by Origin.

Result and Discussion

Effect of Cd Stress on Biomass of *S. arvensis*. It can be seen from Fig. 1 that the growth of *S. arvensis* has not been significantly affected when the concentration of Cd is ≤0.5 mg/kg($P>0.05$), while the growth of Cd concentration is ≥2.0 mg kg^{-1}, which is significantly inhibited ($P< 0.05$), the biomass of Cd concentrations of 1.0 mg/kg and 1.5 mg/kg decreased but not significant. This study showed that Cd has an effect on the biomass growth of *S. arvensis*: low concentration promotion and high concentration inhibition. This is consistent with Furong Li [13] on the effects of lead and cadmium combined pollution on the growth and accumulation of heavy metals in different varieties of *Ipomoer aquatica Forssk*.



Different lowercase letters indicate that the mean difference between treatments is significant (P<0.05), the same below

Fig. 1 Effects of different concentrations of cadmium on *S. arvensis* biomass

Effect of Cd Stress on Chlorophyll Content of *S. arvensis*. It can be seen from Fig. 2 that the chlorophyll content of the *S. arvensis* decreases with the increase of soil Cd concentration. Among them, the low concentration of Cd≤0.5 mg/kg chlorophyll content was slightly lower than the contrast group (P>0.05), and the Cd concentration was 1.5 mg/kg and 2.0 mg kg^{-1}, which was significantly lower than the contrast group. The chlorophyll content of the treatment group with a Cd concentration of 1.0 mg/kg was 10.72% lower than that of the contrast, but it was not significant. This study showed that Cd has an effect on the growth of chlorophyll content in *S. arvensis*: low concentration does not affect, high concentration inhibits. Huizhong Wang [14] and other studies have shown that Cd stress can destroy the chlorophyll structure and reduce the chlorophyll content, which is basically consistent with the results of this experiment.

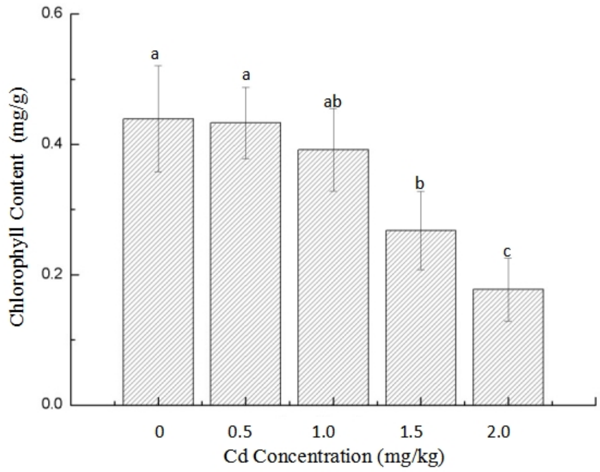


Fig. 2 Effects of different concentrations of cadmium on chlorophyll content in *S. arvensis*

Effects of Cd Stress on the Content of MDA in the Aerial part of *S. arvensis*. As shown in Fig. 3, compared with the contrast group, the MDA content increased significantly in the 0.5 mg/kg Cd treatment group (P<0.05); while in the 1.0 and 1.5 mg/kg Cd treatment group, the MDA content decreased, but not significant. There was no change in the 2.0 mg/kg Cd treatment group. Therefore, a low concentration of Cd can lead to an increase in the MDA content in the *S. arvensis* tissue. This is inconsistent with Yan Li [15] on the results of the *Celastrus orbiculatus Thunb*, which found that the MDA increased continuously with the increase of heavy metal concentration. The reason may be that cumulative H_2O_2 induces an increase in CAT activity, and highly active CAT can effectively eliminate H_2O_2 in cells and reduce MDA content.

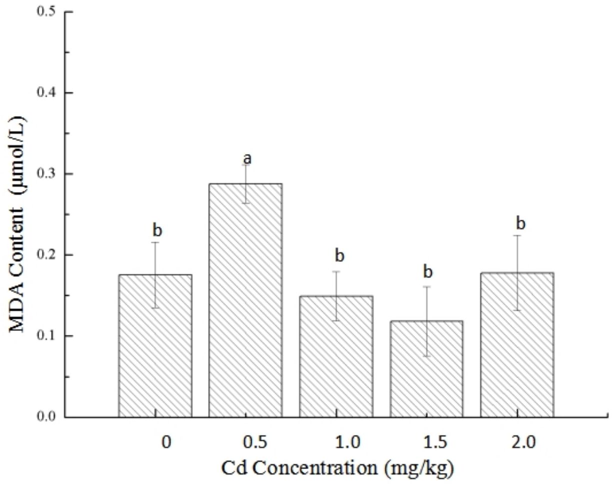


Fig. 3 Effects of different concentrations of cadmium on MDA content in *S. arvensis*

Effects of Cd Stress on POD Activity in the Aerial Part of *S. arvensis*. As shown in Fig. 4, when the concentration of Cd was 0.5 mg/kg and 1.0 mg/kg, the POD activity increased significantly compared with the contrast group, with an increase of 62.75% and 80.39%. The Cd concentration was 1.5 mg/kg, which was 17.65% lower than the contrast group, but not significant. The POD activity decreased significantly by 37.5% when the concentration of Cd was 2.0 mg/ kg. Therefore, the results showed that Cd had an effect on the activity of POD in *S. arvensis*: low concentration promotion and high concentration inhibition. This is basically consistent with the results of Yan Li [15].

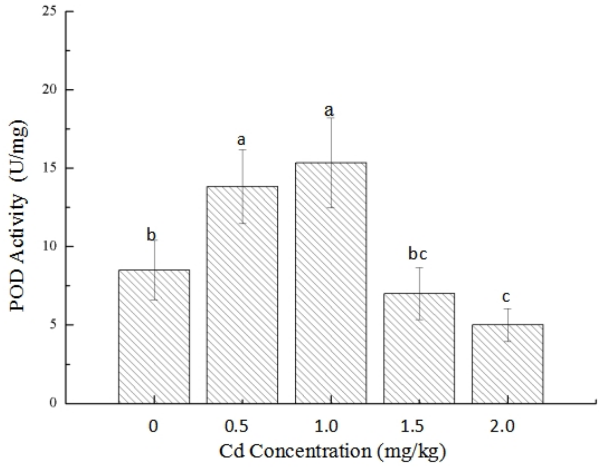


Fig. 4 Effect of different concentrations of cadmium on POD activity in *S. arvensis*

Effects of Cd Stress on SOD Activity in Aerial Parts of *S. arvensis*. As shown in Fig. 5, different concentrations of Cd treated *S. arvensis*, compared with the contrast group, 0.5 mg/kg and 1.0 mg/kg Cd treatment group, SOD activity increased by 12.60% and 2.99%, respectively. The SOD activity of the 1.5 mg/kg and 2.0 mg/kg Cd treatment groups was significantly lower than that of the 1.0 mg/kg Cd treatment group. Therefore, the results show that with the increase of Cd concentration, the activity of SOD increases first and then decreases, which is consistent with the results of Yan Li [15].

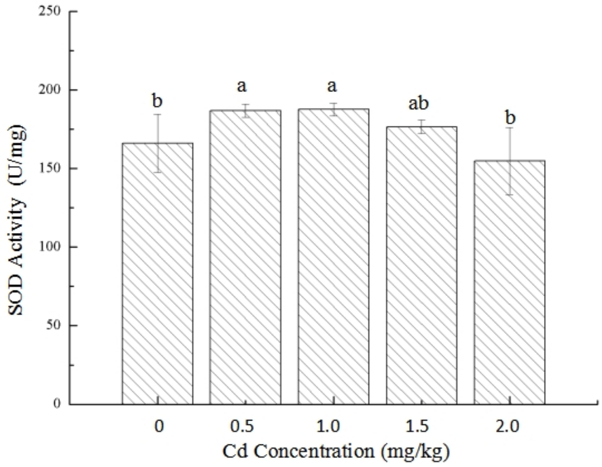


Fig. 5 Effects of different concentrations of cadmium on SOD activity in *S. arvensis*

Effects of Cd Stress on CAT Activity in Aerial Parts of *S. arvensis*. As shown in Fig. 6, when the Cd concentration was 0.5 mg/kg and 1.5 mg/kg, the CAT activity of the *S. arvensis* was significantly increased (P<0.05). When the Cd concentration was 0.5 mg/kg and 2.0 mg/kg,the CAT activity was significantly decreased (P<0.05). When the Cd concentration was 1.0 mg/kg, the CAT activity in the tissue was much lower than that of the 0.5 mg/kg and 1.5 mg/kg experimental groups. It may be that the *S. arvensis* in order to inhibit the production of a large amount of membrane lipid peroxide in the cell, leading to excessive physiological and biochemical reactions of CAT in the body.Therefore, with the increasing concentration of Cd, the activity of CAT enzymes generally increases first and then decreases. This is basically consistent with the re sults of Yan Li [15].

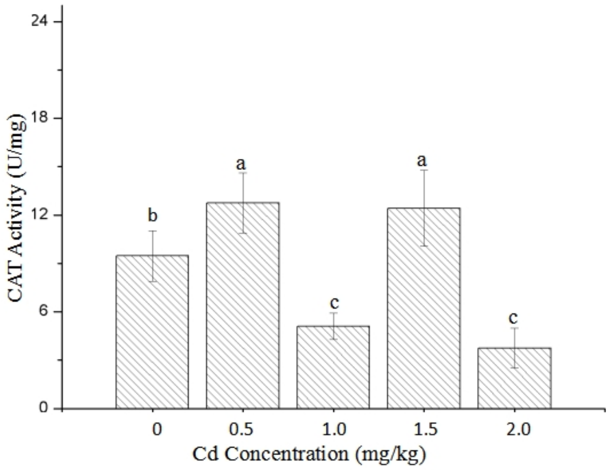


Fig. 6 Effects of different concentrations of cadmium on *S. arvensis* CAT activity

Conclusions

When the concentration of heavy metal Cd in soil was lower than 2.0 mg/kg, the biomass of *S. arvensis* was promoted at low concentration of Cd, and the chlorophyll content was not significant. The activity of antioxidant enzymes in the *S. arvensis* was increased at the concentration of Cd of a certain range. The MDA showed an increasing trend when treated with low concentration of Cd. The *S. arvensis* showed high tolerance to Cd stress. So, when the concentration of Cd is low, the Cd in the contaminated soil can be fixed by using *S. arvensis* ,and reduce the pollution of Cd in the soil. Therefore, the *S. arvensis* has a great application potential in the repair of Cd contaminated soil.

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