

Effects of Mixing Hyperaccumulated Straw and Phosphate Rock Powder on Cd Content in Chinese Cabbage

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Abstract. In this paper, hyperaccumulator straw (*Solanum nigrum* L., *Amaranthus chinense* L., and *Siegesbeckia orientalis* L.) and phosphate rock powder were selected as materials, a pot experiment was used to study the effects of three compounding modifiers on the growth, nutritional quality and cadmium (Cd) content of Chinese cabbage. The results showed that: (1) The combination of *Siegesbeckia orientalis* + phosphate rock powder can significantly promote the growth of Chinese cabbage, while *Solanum nigrum* + phosphate rock powder and *Amaranthus chinense* + phosphate rock powder have no effect on the growth of Chinese cabbage. (2) The combination of *Solanum nigrum* and phosphate rock powder increased the content of soluble sugar, soluble protein and VC in shoots of Chinese cabbage by 64.33%, 16.27% and 2.2%, respectively, and the nitrite content decreased by 34.58%, which improved the quality of Chinese cabbage. (3) Different compounding modifiers can significantly reduce the Cd content in shoots of Chinese cabbage, and the reduction of *Solanum nigrum* + phosphate rock powder is the largest, reaching 61.29%. In conclusion, all three modifiers can improve the nutritional quality and reduce the Cd content in the shoots of Chinese cabbage, and *Solanum nigrum* + phosphate rock powder has the best effect.

1 Introduction

At present, the area of cultivated land polluted by heavy metal cadmium (Cd) in China is about 1.3×10^4 hectare, involving 25 regions in 11 provinces and municipalities. The annual production of Cd content exceeded the standard of agricultural products up to 1.46×10^6 ton [2]. Cd in soil is easily absorbed by plants and enriched in plants. Some studies have shown that the order of heavy metal enrichment ability of different vegetable types is leaf vegetables > eggplants and fruits > rhizomes > melons > legumes. Vegetables play an important role in people's daily diet structure, and their quality is directly related to human health. Therefore, it is particularly important to find suitable methods to remediate Cd contaminated soil and reduce Cd content in crops.

Common techniques for remediation of heavy metals in soil include agricultural engineering measures, biological remediation, chemical remediation and physical remediation. At present, in-situ passivation remediation technology has become a research hotspot for the treatment of heavy metal contaminated soil due to its rich resources, low cost and easy operation. How to select safe and effective passivation materials according to the nature of soil and pollution status is the key to the implementation of this method. The passivation remediation effects of different materials vary significantly with soil properties, types and degrees of heavy metal contamination, types and dosages of materials [4]. Previous study found that red mud and

rape straw combined application could effectively reduce cadmium content in soil and tobacco leaves. And the combined application of calcium magnesium phosphate fertilizer and peat could not only effectively reduce the Cd content of cabbage shoots, but also avoid phosphorus loss and cost waste caused by excessive application of phosphorus fertilizer [5]. At present, in-situ passivation remediation technology research, the use of straw returning to the field to remediate soil heavy metal pollution is mostly concentrated in field crops, and the research on enriched plant straw and inorganic materials as passivators to remediate soil heavy metal pollution is less.

Solanum nigrum L., *Amaranthus chinense* L., and *Siegesbeckia orientalis* L. are Cd-accumulating plant materials, which are widely distributed in China and have large biomass and rapid growth. Phosphate mineral powder can form precipitation of phosphate heavy metals with heavy metal ions in soil solution, thus reducing the availability of heavy metals in polluted soil. Therefore, pot experiments were conducted to study the effects of phosphate rock powder and hyperaccumulated plant straw on the quality and Cd content of Chinese cabbage grown on Cd-contaminated soils, using *Solanum nigrum* L., *Amaranthus chinense* L., and *Siegesbeckia orientalis* L. as test materials and Chinese cabbage as indicator plant, in order to restore Cd-contaminated soils in situ passivation. And to provide theoretical reference for the safe production of vegetables.

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2 Materials and Methods

2.1 Materials

Cd polluted soil: Paddy soil was used in the experiment. The soil pH was 6.49, and the total nitrogen (TN), available phosphorus (AP) and available potassium (AK) contents were $758.84 \text{ mg}\cdot\text{kg}^{-1}$, $38.47 \text{ mg}\cdot\text{kg}^{-1}$ and $78.93 \text{ mg}\cdot\text{kg}^{-1}$, respectively. The total Cd content in soil was $4.89 \text{ mg}\cdot\text{kg}^{-1}$.

Chinese cabbage: The variety of cabbage is four seasons cabbage.

The straw of *Solanum nigrum* L., *Amaranthus chinense* L., and *Siegesbeckia orientalis* L.: Straw was collected from Chongzhou Base of Sichuan Agricultural University and was not polluted by heavy metals. The plant straw was dried and pulverized with a micro-plant sample pulverizer (pore size of 1 mm).

Phosphate rock powder: Phosphate rock powder was purchased from Sichuan Jinxin Mineral Products Co., Ltd., after grinding, pass through 100 mesh sieve.

2.2 Experimental Design

Using indoor culture experiments, 6 kg of Cd polluted soil was weighed and placed in a $10 \times 20 \times 30$ cm non-porous plastic basin. The phosphate rock powder and straw of *Solanum nigrum*, *Amaranthus chinense* and *Siegesbeckia orientalis* were added to the soil. At the same time, the control (CK) was set without adding any substance. And each treatment was repeated 3 times. The concentration of modifier in each treatment was shown in Table 1.

After soaking and germination, the Chinese cabbage is sown in the soil, 6 plants per pot. After 30 days of treatment, sampling to determine the various indicators.

Table1. Concentration of modifier in each treatment

Treatment	<i>Solanum nigrum</i>	<i>Siegesbeckia orientalis</i>	<i>Amaranthus chinense</i>	Phosphate rock powder
CK	0	0	0	0
TL	1%			2%
TX		1%		2%
TZ			1%	2%

2.3 Experimental Methods

Plant dry weight and fresh weight were measured by weighing method. The soluble sugar content was determined by anthrone colorimetry method [6]. Soluble protein content was determined by Coomassie Brilliant Blue G-250 method[6]. VC content was determined by 2, 6-dichloroindophenol titration [6]. Nitrite content was determined by Ultraviolet Spectrophotometry [6]. Cd content was digested by wet ashing method and determined by atomic absorption spectrometry (AAS).

2.4 Data Statistics and Analysis

Statistical analyses were performed using Microsoft Excel 2016 and SPSS 22.0 statistical software. Data were analyzed by one-way ANOVA with least significant difference (LSD) at 5% confidence level.

3 Results and Discussion

3.1 Effect of Modifier on Growth of Chinese Cabbage

As shown in Table 2, the application of three kinds of modifier can promote the growth of Chinese cabbage. The fresh and dry weight in shoots of Chinese cabbage with TX treatment were significantly higher than those treated with TZ, TL and CK. There was no significant difference in fresh and dry weight of shoots between TZ and TL and CK. And there was no significant difference in fresh and dry weight of roots between TX, TZ, TL and CK. Different combinations of modifiers can promote the growth of cabbage, the reason may be that different combinations of modifiers change the physical and chemical properties of soil, and at the same time, the N, P and K elements in phosphate powder and straw also promote the growth of Chinese cabbage [7].

Table2. The biomass and Cd content of Chinese cabbage under different treatments

Treatment	Fresh weight ($\text{g}\cdot\text{plant}^{-1}$)		Dry weight ($\text{g}\cdot\text{plant}^{-1}$)		Cd content ($\text{mg}\cdot\text{kg}^{-1}$)
	shoot	root	shoot	root	
CK	$19.06\pm 7.33\text{b}$	$0.55\pm 0.24\text{a}$	$1.14\pm 0.41\text{b}$	$0.07\pm 0.03\text{a}$	$1.08\pm 0.09\text{a}$
TL	$21.25\pm 5.89\text{b}$	$0.64\pm 0.16\text{a}$	$1.46\pm 0.27\text{b}$	$0.07\pm 0.01\text{a}$	$0.42\pm 0.05\text{c}$
TX	$39.90\pm 4.70\text{a}$	$0.72\pm 0.18\text{a}$	$2.41\pm 0.34\text{a}$	$0.09\pm 0.01\text{a}$	$0.51\pm 0.07\text{c}$
TZ	$27.42\pm 3.08\text{b}$	$0.58\pm 0.10\text{a}$	$1.63\pm 0.70\text{b}$	$0.07\pm 0.01\text{a}$	$0.69\pm 0.06\text{b}$

Note: Different letters in each column indicate significant differences ($P < 0.05$) among different treatments.

3.2 Effects of Modifier on Nutritional Quality of Chinese Cabbage

As shown in Figure.1, after applying three kinds of modifiers, the nutritional quality of Chinese cabbage changed in varying degrees. The soluble protein content of Chinese cabbage treated with TL increased

significantly, which was 23.67% higher than that of CK, and the soluble protein content in TX and TZ treatment was significantly lower than that of CK, which decreased by 11.12% and 36.57% respectively.

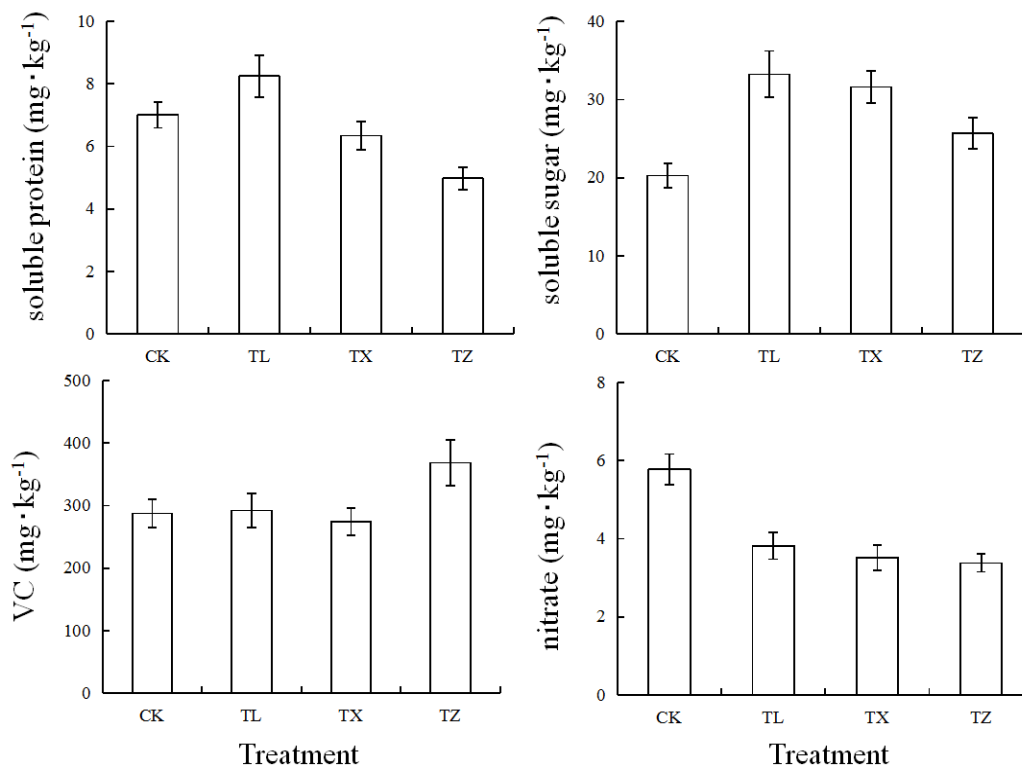


Fig. 1. Nutritional quality of Chinese cabbage

The soluble sugar content of Chinese cabbage in TL treatment is the highest, significantly higher than that in CK. The soluble sugar content in TX and TZ treatment was not significantly different from CK, and there was no difference between TL, TZ and TX treatment.

The VC content of Chinese cabbage in TZ treatment was significantly higher than CK, but there was no significant difference between TL, TX treatment and CK.

After applying three kinds of modifiers, the nitrate content in Chinese cabbage decreased significantly. And TZ treatment decreased the most, which was 39.77%, and there was no difference between TL, TZ and TX treatments.

3.3 Effects of Modifier on Cd Content of Chinese Cabbage

After application of the three kinds of modifiers, the Cd content in shoots of Chinese cabbage was significantly lower than that in CK, and the Cd content in shoots of Chinese cabbage in TX and TL treatment was significantly lower than that in TZ treatment (Table 2). The decrease of Cd content in shoots of Chinese cabbage may be due to the fact that the application of straw in the soil can change the chemical form of heavy metals, and

convert the heavy metals into organic bound, oxide bound or residual state in the soil, thereby reducing the availability of heavy metals, and inhibiting the uptake of heavy metals by crops [8,9]. On the other hand, the phosphate in the straw or phosphate rock powder can form precipitation with Cd²⁺ in the soil solution or directly adsorb the heavy metals on the phosphate surface to stabilize the Cd²⁺ in the soil, thus reducing the Cd content in the shoots of Chinese cabbage [10].

4 Conclusion

The combination of three kinds of modifiers can promote the growth of Chinese cabbage, improves the nutritional quality, and reduces the content of nitrite and Cd in Chinese cabbage. And the combination of *Solanum nigrum* straw and phosphate rock powder has the best effect.

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