Effects of hyperaccumulator plant straw on biomass and cadmium accumulation of lettuce

Le Liang¹, Ran Zhang², Yan Zhao², Ying Zhu², Qiaoman Ao² and Yi Tang^{1*}

¹Institute of Pomology and Olericulture, Sichuan Agricultural University, Chengdu, Sichuan, 611130, China

²College of Horticulture, Sichuan Agricultural University, Chengdu, Sichuan, 611130, China

Abstract. To study the effects of hyper-accumulator plant straw on the biomass and cadmium (Cd) accumulation of lettuce (*Lactuca sativa*), the pot experiments were conducted to study the effects of straw application of three hyper-accumulator plants (*Solanum nigrum*, *Bidens pilosa* and *Galinsoga parviflora*) on the biomass and Cd accumulation of lettuce under Cd stress. The results show that: compared with no straw application, the biomass of lettuce was increased after applying three kinds of hyper-accumulator plant straw: *S. nigrum*, *B. pilosa* and *G. parviflora*, Cd content in the above ground part of lettuce was increased by 4.46%, 1.20% and 0.63% respectively, compared with that of non-application, and Cd content in the root of lettuce was decreased. The application of three kinds of hyperaccumulator plant straw promoted the growth of lettuce and increased Cd uptake by lettuce of aerial part.

1 Introduction

Straw returning is an effective ecological agricultural measure, and straw will release organic matter, nitrogen, phosphorus, potassium and other nutrients after decomposition, and can improve the physical and chemical properties of soil, enhance the activity of biological and most enzymes, and promote the growth and development of stubble crops and increase yield [1-2]. Because of various industrial activities, cadmium (Cd) accumulates within the soil and has the ability to remain the food chain for extended periods of time, poses a significant health risk to humans [3]. Lettuce (*Lactuca sativa*) is an important leafy vegetable crop that produces great wealth, which typically accumulate significantly more Cd in their edible parts than other vegetables [4-5]. *Solanum nigrum*, *Bidens pilosa* and *Galinsoga parviflora* are common hyperaccumulator plants in farmland, which have the characteristics of wide source, convenient collection, large number and wide distribution. This experiment explored the effects of application of hyperaccumulator plant straw on the growth and Cd accumulation of lettuce under Cd pollution conditions, and provided reference for the safe production of lettuce in the future.

2 Materials and Methods

2.1. Experiment Materials

In June 2015, three kinds of Cd hyperaccumulator plants were collected from the surrounding farmland (not contaminated by heavy metals) in the Sichuan

Agriculture University: *S. nigrum*, *B. pilosa* and *G. parviflora*, after removing the seeds, they are washed with distilled water. After 15 minutes of killing fresh at 105 °C, they are dried to constant weight at 75 °C. Cutting the dried straw into about 1 cm segments and set aside.

Lettuce is a common glass lettuce in Sichuan, it has high purity, good quality, good tolerance and resistance, and can be planted all year round and sustainable harvest for more than 50 days.

The tested soil was paddy soil, which was taken from farmland not polluted by heavy metals around Chengdu campus of Sichuan Agricultural University, and its basic physical and chemical properties are as follows: pH 6.36, organic matter 18.10 g/kg, total nitrogen 1.04 g/kg, total phosphorus 1.36 g/kg, total potassium 20.78 g/kg, hydrolyzable nitrogen 43.90 mg/kg, available phosphorus 92.71 mg/kg, available potassium 134.25 mg/kg, available Cd not was detected. CdCl₂·2.5H₂O analytical pure solution was added to the tested soil for heavy metal Cd.

2.2 .Experiment Method

In June 2015, the air-dried and crushed soil was sifted through 300 meshes and loaded into barrels, each containing 20 kg. The Cd concentration was 10 mg/kg by adding analytical pure CdCl₂·2.5 H₂O solution [6], after 30 days of moist storage, all contaminated soils are fully blended and packed in a pot of 3 kg per pot.

Full lettuce seeds were select for disinfection, evenly spread them on wet gauze, put them into 20 °C light incubator for germination, and then sow them in a pot dish with nutritive soil to raise seedlings. After one week

*Corresponding author's e-mail: 95459425@qq.com

of lettuce seedling raising, three kinds of hyperaccumulator plant straw were applied to the prepared Cd contaminated soil, 6 g per pot, and mixed evenly, with no straw as the control. The experiment was divided into four treatments: no straw, *S. nigrum* straw, *B. pilosa* straw and *G. parviflora* straw. After a week of balancing and watering, select healthy lettuce seedlings and transplant them into Cd-contaminated soil prepared with straw. Four plants were transplanted in each pot and nine pots were treated in each pot. After transplanting, the seedlings were placed in plastic greenhouse, and the soil moisture was maintained at about 80%. After the lettuce grew 50d, the Cd content in lettuce plants was measured, the intact roots were removed, and the root and shoot were washed with tap water respectively, then rinsed with deionized water for 3 times, dried and weighed separately. Finally, the shoot and root were killed fresh at 110 °C for 15 min, and dried at 75 °C to constant weight. The Cd content in root was measured after weighing.

2.3. Statistical analyses

All data are collated with Excel 2010 software; SPSS 20.0 was used for variance analysis and Duncan's new complex range method was used for multiple comparisons. Root-shoot ratio = root dry weight / shoot dry weight [7]; transport coefficient = Cd content in shoot/Cd content in root [8].

3 Results

3.1. Effects of soil application of hyperaccumulator plant straw on biomass of lettuce

Application of hyperaccumulator plant straw promoted the growth of lettuce, the fresh weight of shoot and root of lettuce was significantly higher than that of the control (Table 1). Compared with the control, the shoot fresh weight of lettuce with application *S. nigrum* straw, *B. pilosa* straw and *G. parviflora* straw increased by 18.11% ($P < 0.05$), 15.31% ($P < 0.05$) and 21.65% ($P < 0.05$). The fresh root weight of lettuce in each treatment from high to low was as follows: *S. nigrum* straw > *G. parviflora* straw > *B. pilosa* straw > no straw. All treatments were significantly higher than the control, but there was no difference among the treatments. The shoot dry weight of lettuce treated with *G. parviflora* straw was significantly higher than that of the control, which was 16.82% higher than that of the control ($P < 0.05$). Compared with the control, the dry weight of lettuce root increased by 62.50% ($P < 0.05$), 50.00% ($P < 0.05$) and 70.83% ($P < 0.05$) with the application of *S. nigrum* straw, *B. pilosa* straw and *G. parviflora* straw. The root-shoot ratio of lettuce with hyperaccumulate plant straw was higher than those without straw.

Table 1. Effects of hyperaccumulate plant straw on the biomass of lettuce

Plant straw	Shoot fresh weight (g /plant)	Root fresh weight (g/plant)	Shoot dry weight (g /plant)	Root dry weight (g /plant)	Root shoot ratio
No straw	59.13±2.10d	3.02±0.20b	2.20±0.14b	0.24±0.01b	0.11
<i>S. nigrum</i> straw	69.84±0.35b	4.58±0.21a	2.42±0.07b	0.39±0.03a	0.16
<i>B. pilosa</i> straw	68.18±2.74c	4.42±0.45a	2.24±0.14b	0.36±0.03a	0.16
<i>G. parviflora</i> straw	71.93±3.78a	4.54±0.21a	2.57±0.21a	0.41±0.02a	0.16

Different lowercase letters in the same column indicate significant difference ($P < 0.05$).

3.2. Effects of soil application of hyperaccumulator plant straw on Cd content in lettuce

Application of *S. nigrum* straw, *B. pilosa* straw and *G. parviflora* straw promoted the accumulation of Cd in the shoot parts of lettuce, Cd content in lettuce shoot increased by 4.46% ($P < 0.05$), 1.20% ($P < 0.05$) and 0.63% ($P < 0.05$) compared with the control, respectively

(Table 2). The application of hyperaccumulator plant straw significantly reduced the Cd content in lettuce root. The order of Cd content in lettuce root was from high to low: no straw > *S. nigrum* straw > *G. parviflora* straw > *B. pilosa* straw. Cd content in root of lettuce treated with *S. nigrum* straw, *B. pilosa* straw and *G. parviflora* straw decreased by 28.19% ($P < 0.05$), 32.70% ($P < 0.05$) and 28.62% ($P < 0.05$) respectively, compared with the control. Cd transport coefficient of lettuce was increased by applying hyperaccumulator plant straw, and the highest was applied with *B. pilosa* straw.

Table 2 Effects of hyperaccumulate plant straw on the content of lettuce

Plant straw	Shoot Cd content (µg/g DW)	Root Cd content (µg/g DW)	Transport coefficient
No straw	32.53±0.52c	91.28±1.06a	0.36
<i>S. nigrum</i> straw	33.98±0.01a	65.55±0.57b	0.52
<i>B. pilosa</i> straw	32.92±0.33b	61.43±0.74d	0.54
<i>G. parviflora</i> straw	33.71±0.40a	65.16±0.41c	0.52

Different lowercase letters in the same column indicate significant difference ($P < 0.05$).

4 Conclusion

Application of hyperaccumulator plants in soil (*S. nigrum*, *B. pilosa* and *G. parviflora*) increased the shoot and root biomass of lettuce, and increased the Cd content and Cd transport coefficient of lettuce shoot. So under the condition of Cd pollution, three kinds of hyperaccumulator plants straw were applied (*S. nigrum* straw, *B. pilosa* straw and *G. parviflora* straw) it is conducive to the normal growth of lettuce, but not conducive to safe production.

References

1. Meng, J., Cao, Y., Yao, Y., Wang, J. (2013) Research progress on the effects of straw returning on soil physicochemical and biological characters. Northern Horticulture, 11:184-186.
2. Mu, P., Zhang E.H., Wang, H.N., Fang, Y.F. (2011) Effects of straw returning on soil physical and chemical properties and microbial biomass in maize tillage layer for many years. Journal of Soil and Water Conservation, 25(5):81-85.
3. Yazdia, M., Kolahib, M., Mohajel Kazemic, E., Goldson Barnabyd, A. (2019) Study of the contamination rate and change in growth features of lettuce (*Lactuca sativa* Linn.) in response to cadmium and a survey of its phytochelatin synthase gene. Ecotoxicology and Environmental Safety, 180:295-308.
4. Jo-Anne, E. Cavanagh, Yi, Z., Gray, C.W., Munir, K., Lehto, N., Robinson, B.H. (2019) Cadmium uptake by onions, lettuce and spinach in New Zealand: Implications for management to meet regulatory limits. Science of the Total Environment, 668:780-789.
5. Hirpassaa, W. D., Codling, Eton E. (2019) Growth and Metal Uptake of Lettuce [*Lactuca sativa* L.] on Soil Amended with Biosolids and Gypsum. Communications in Soil Science and Plant Analysis, 50:16, 2033-2040.
6. Lin, L., Liu, Q., Shi, J., Sun, J., Liao, M., Mei, L. (2014) Intercropping different varieties of radish can increase cadmium accumulation in radish. Environmental Toxicology and Chemistry, 33(9): 1950-1955.
7. Kuliková, Z. L., Lu, A. (2010) Silicon influence on maize, *Zea mays* L., hybrids exposed to cadmium treatment. Bulletin of environmental contamination and toxicology, 85(3): 243-250.
8. Rastmanesh, F., Moore, F., Keshavarzi, B. (2010) Speciation and phytoavailability of heavy metals in contaminated soils in Sarcheshmeh area, Kerman Province, Iran. Bulletin of environmental contamination and toxicology, 85(5): 515-519.