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Effects of Mulching with Hyperaccumulator Straw on Nutrients Uptake of *Cyphomandra betacea* Seedlings under Cadmium Stress

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Abstract: A pot experiment was carried out to study effects of mulching with four hyperaccumulator (*Solanum photeinocarpum*, *Tagetes erecta*, *Galinsoga parviflora* and *Bidens pilosa*) straws on the total phosphorus and total potassium content in all parts of *Cyphomandra betacea* seedlings under cadmium stress. The results showed that different hyperaccumulator straw had different effects on nutrients uptake of *C. betacea* seedlings. Compared with the uncovered, mulching with *G. parviflora* straw not only maximized the roots and stems total phosphorus content in *C. betacea* seedlings, but also maximized the roots and shoots total potassium content in *C. betacea* seedlings under cadmium stress. Therefore, mulching with *G. parviflora* straw could significantly promote the nutrients uptake of *C. betacea* seedlings and provide references for improving nutrients absorption of fruit trees in cadmium contaminated soil.

Introduction

Soil is the basis for human survival. However, with the rapid development of industry and the irregular use of chemical fertilizers and pesticides, a large amount of heavy metals are released into the soil, causing large areas of soil contamination with heavy metals [1]. Cadmium (Cd) is considered to be one of the most biologically toxic heavy metals and not only can easily accumulate in the soil for a long time, but also can harm human health through the food chain [2]. In addition, Cd has a significant inhibitory effect on soil enzymes and microorganisms, and can inhibit the absorption of soil nutrients by plants [3]. Therefore, it is of great significance to study how to increase the absorption of nutrients by plants under Cd stress. Straw return to soil is an important measure to improve soil physical and chemical properties and soil fertility [4]. Straw is rich in a large number of mineral elements such as nitrogen, phosphorus, potassium and organic matter, which can return these mineral elements to the soil for plant absorption and reuse [5]. Hyperaccumulators refer to the heavy metals content in plants shoots above a certain level and the content of heavy metals in plants shoots is higher than that of roots [6]. The study showed that applying different hyperaccumulators straws to the Cd-contaminated soil not only increased the biomass and leaves SPAD of accumulator plant *Capsella bursa-pastoris* but also improved the Cd accumulation in all parts of *Capsella bursa-pastoris* [7]. And it has been reported that applying different hyperaccumulators straws to Cd-contaminated soil had different effects on photosynthetic characteristics and soluble sugar content of hyperaccumulator *Galinsoga parviflora* [8]. However, the effects of mulching hyperaccumulator straws on ordinary plants have not been report. *Cyphomandra betacea* is a perennial evergreen shrub of the genus Solanaceae, which combines ornamental and edible values with rich vitamins and beneficial trace elements [9]. The purpose of this study was to seek out the hyperaccumulators (*Solanum photeinocarpum* [10], *Tagetes erecta* [11], *Galinsoga parviflora* [12], *Bidens pilosa* [13]) straws which could promote the nutrients uptake of *C. betacea* seedlings.

Materials and Methods

Materials collection. The shoots of four hyperaccumulators (*S. photeinocarpum*, *T. erecta*, *G. parviflora*, *B. pilosa*) and soil were collected from the farmland of Ya'an Campus of Sichuan Agricultural University (not polluted by Cd) in June, 2014. And fixed all plants at 110°C for 15 minutes and dried at 80°C until they were weighed after washing them with deionized water. Then cut into small pieces of less than 1 cm by scissors and stored. The seeds of *C. betacea* were collected from three-years of fruitful *C. betacea* from the Ya'an Campus of Sichuan Agricultural University in October 2013. And the seeds of *C. betacea* were sowed in the sand plate in June 2014.

Experimental Design. The experiment was conducted in farm of Ya'an Campus of Sichuan Agricultural University. In June 2014, the unpolluted soil was air-dried and passed through a 5-mm sieve. 3 kg air-dried soil was weighed into each plastic pot (15 cm high, 18 cm in diameter), soaking uniformly $CdCl_2 \cdot 2.5H_2O$ by 10 mg/kg and balanced for 4 weeks. In July 2014, the straws of four hyperaccumulators were separately mulched in Cd-contaminated soil surface. Coverage was 6g per pot and the water was kept moist and equilibrated for one week. Then, the same growth *C. betacea* with the four real leaves were transplanted into the pots. Two plants were planted in each pot. Five replicates per treatment and all pots were watered each day to keep the soil moisture about 80%. The distance between pots was 15 cm, and the pot position exchanged aperiodically to weaken the impact of the marginal effects. After 40 days, all *C. betacea* seedlings were harvested and divided, fixed all plants at 110°C for 15 minutes and dried at 80°C until they were weighed after washing them with deionized water. The total phosphorus content of *C. betacea* seedlings were determined by molybdenum antimony colorimetric method [14]. The total potassium content of *C. betacea* seedlings were determined by flame spectrophotometer [14].

Statistical Analyses. Statistical analyses were conducted using statistical software of SPSS 17.0. Data were analyzed by one-way ANOVA with least significant difference at 5% confidence level.

Results and Discussion

Total phosphorus content in *C. betacea* seedlings. For the roots of *C. betacea* seedlings, mulching with hyperaccumulators straws could increase its total phosphorus content in varying degress compared to the uncovered (Table 1). The order of roots total phosphorus content in *C. betacea* seedlings from large to small was ranked: *G. parviflora*, *S. photeinocarpum*, *T. erecta*, *B. pilosa*, uncovered. And mulching with *G. parviflora* straw increased the total phosphorus content of the roots in *C. betacea* seedlings by 41.30% ($P < 0.05$) compared with the uncovered. For the stems of *C. betacea* seedlings, only mulching with *G. parviflora* straw increased its total phosphorus content, other hyperaccumulators straws all reduced its total phosphorus content compared with uncovered. The order of leaves total phosphorus content in *C. betacea* seedlings from large to small was ranked: *B. pilosa*, uncovered, *G. parviflora*, *S. photeinocarpum*, *T. erecta*. And mulching with *B. pilosa* straw increased the total phosphorus content of the leaves in *C. betacea* seedlings by 18.11% ($P < 0.05$) compared with the uncovered. For the shoots of *C. betacea* seedlings, mulching with hyperaccumulators straws reduced its total phosphorus content compared with the uncovered. And mulching with *T. erecta* straw reduced the total phosphorus content of the shoots in *C. betacea* seedlings by 18.32% ($P < 0.05$) compared with the uncovered.

Table 1 Total phosphorus content in *C. betacea* seedlings

hyperaccumulator straw	Roots (g/kg)	Stems (g/kg)	Leaves (g/kg)	Shoots (g/kg)
Uncovered	0.247±0.006cd	0.345±0.014a	0.519±0.034b	0.464±0.032a
S. photeinocarpum	0.292±0.011b	0.298±0.007b	0.460±0.017c	0.406±0.020c
T. erecta	0.288±0.021b	0.278±0.020b	0.429±0.026d	0.379±0.016d
G. parviflora	0.349±0.024a	0.357±0.022a	0.498±0.023bc	0.450±0.031ab
B. pilosa	0.255±0.009c	0.059±0.003c	0.613±0.031a	0.436±0.012b

Means with the same letter within each column are not significantly different at $p < 0.05$.

Total potassium content in *C. betacea* seedlings. For the roots of *C. betacea* seedlings, mulching with hyperaccumulators straws could significantly increase its total potassium content compared with the uncovered (Table 2). The order of roots total potassium content in *C. betacea* seedlings from large to small was ranked: *G. parviflora*, *B. pilosa*, *S. photeinocarpum*, *T. erecta*, uncovered. And mulching with *G. parviflora* straw increased the total potassium content of the roots in *C. betacea* seedlings by 94.84% ($P < 0.05$) compared with the uncovered. For the stems of *C. betacea* seedlings, only mulching with *T. erecta* straw significantly reduced its total potassium content compared with the uncovered, other hyperaccumulators straws all increased its total potassium. And the order of stems total potassium content in *C. betacea* seedlings from large to small was ranked: *G. parviflora*, *S. photeinocarpum*, *B. pilosa*, uncovered, *T. erecta*. The order of leaves total potassium content in *C. betacea* seedlings from large to small was ranked: *B. pilosa*, *G. parviflora*, uncovered, *S. photeinocarpum*, *T. erecta*. And mulching with *B. pilosa* straw increased the total potassium content of the leaves in *C. betacea* seedlings by 14.01% ($P < 0.05$) compared with the uncovered. For the shoots of *C. betacea* seedlings, only mulching with *T. erecta* straw significantly reduced its total potassium content by 23.27% compared with the uncovered, other hyperaccumulators straws all increased its total potassium. And the order of shoots total potassium content in *C. betacea* seedlings from large to small was ranked: *G. parviflora*, *B. pilosa*, *S. photeinocarpum*, uncovered, *T. erecta*.

Table 2 Total potassium content in *C. betacea* seedlings

hyperaccumulator straw	Roots (g/kg)	Stems (g/kg)	Leaves (g/kg)	Shoots (g/kg)
Uncovered	21.90±0.47d	26.96±0.94c	36.41±1.57b	33.44±0.92c
S. photeinocarpum	34.73±1.02b	30.86±1.26b	35.97±1.05b	34.25±0.53c
T. erecta	31.83±0.84c	20.20±0.57d	28.40±0.84c	25.66±0.42d
G. parviflora	42.67±1.18a	47.38±1.49a	37.67±0.88b	40.96±1.65a
B. pilosa	35.56±1.33b	28.97±1.11bc	41.51±1.43a	37.50±1.60b

Means with the same letter within each column are not significantly different at $p < 0.05$.

Conclusions

In cadmium contaminated soil, planted *Cyphomandra betacea* after mulching with *Solanum photeinocarpum*, *Tagetes erecta*, *Galinsoga parviflora* and *Bidens pilosa* straws could affect the content of total phosphorus and total potassium in *Cyphomandra betacea* seedlings. For the content of total phosphorus *C. betacea* seedlings, mulching with *G. parviflora* straw maximized the roots and stems total phosphorus content in all treatments. And only mulching with *B. pilosa* straw significantly increased the leaves total phosphorus content of *C. betacea* seedlings, other hyperaccumulators straws all reduced the total phosphorus content of *C. betacea* seedlings. And the order of shoots total phosphorus content in *C. betacea* seedlings from large to small was ranked: uncovered, *G. parviflora*, *B. pilosa*, *S. photeinocarpum*, *T. erecta*. These results indicated that mulching with hyperaccumulators straws could improve the roots total phosphorus content in *C. betacea* seedlings, but reduce the shoots total phosphorus content in *C. betacea* seedlings. For the roots of *C. betacea* seedlings, mulching with all hyperaccumulators straws could significantly increase its total potassium content compared with the uncovered. And for the stems of *C. betacea* seedlings, mulching with *G. parviflora* and *S. photeinocarpum* straws could significantly increase the stems total potassium in *C. betacea* seedlings. In addition, mulching with *G. parviflora* straw significantly increased the leaves total potassium content in *C. betacea* seedlings, and mulching with *T. erecta* straw significantly reduced the leaves total potassium content in *C. betacea* seedlings. For the shoots of *C. betacea* seedlings, only mulching with *G. parviflora* and *B. pilosa* straws could significantly increase its total potassium content compared with the uncovered. And in all hyperaccumulators straws, the total potassium content of roots, stems, shoots in *C. betacea* seedlings were highest by mulching with *G. parviflora* straw. These results indicated that mulching with *G. parviflora* straw not only maximized the roots and stems total phosphorus content in *C. betacea* seedlings, but also maximized the roots and shoots total potassium content in *C. betacea* seedlings under cadmium stress. Therefore, mulching with *G. parviflora* straw could significantly promote the nutrients uptake of *C. betacea* seedlings in cadmium contaminated soil.

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