

Effects of Mulching with Hyperaccumulator Straw on Growth and Cadmium Content of Grape Seedlings under Cadmium Stress

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Abstract. A pot experiment was conducted to study the effects of mulching with straw of different cadmium hyperaccumulators (*Crassocephalum crepidioides*, *Galinsoga parviflora*, *Youngia japonica* and *Gnaphalium affine*) on the growth and cadmium content of grape seedlings under cadmium stress. The results showed that mulching with straw of cadmium hyperaccumulators could increase the biomass of grape seedlings commonly. The cadmium content in root of all the straw-mulch treatments except mulching with *G. parviflora* was higher than monoculture, but all the straw-mulch treatments decreased cadmium content in stem, leaf and shoot. Especially, the biomass of root and shoot of grape seedlings for the treatment of mulching with straw of *G. parviflora* reached maximum, which were 85.68% and 22.73% higher than monoculture, respectively. Mulching with straw of *G. parviflora* decreased the content of cadmium in root and shoot of grape seedlings. The cadmium content in root and shoot for the treatment was lowest, and it decreased by 2.13% and 27.82% respectively compared with monoculture. In conclusion, mulching with straw of cadmium hyperaccumulators could promote the growth of grape seedlings, and decrease cadmium content in shoot of grape seedlings, and *G. parviflora* straw worked best.

1.Introduction

Cadmium is a non-essential element that negatively affects plant growth and development. It inhibits plant growth by affecting photosynthesis, the uptake and use of mineral elements, and antioxidant enzyme systems [1-4]. Straw returning into field can promote or inhibit the growth of plant because of allelopathy. Allelopathy is a direct or indirect, harmful or beneficial effect of chemicals produced during plant growth or decay on surrounding plants (including microbes) [5]. Studies showed that allelochemicals released by plant straw could act on other plant roots, affect the absorption of nutrients by roots, and thus affected the growth of plant [6-7], and allelochemicals can form soluble complexes with heavy metals to reduce the bioavailability of heavy metals and reducing their damage to plants [8-9]. Current studies have shown that some cadmium hyperaccumulator straw can promote the growth and affect cadmium accumulation characteristics of cadmium hyperaccumulators, others are the opposite [10-12]. However, there are few studies on the effects of cadmium hyperaccumulator straw on non-enriched plants. Therefore, in the study, four kinds of cadmium hyperaccumulators (*Crassocephalum crepidioides* [13], *Galinsoga parviflora* [14], *Youngia japonica* [15] and *Gnaphalium affine* [16]) straws were mulched on the surface of cadmium contaminated soil, then



cultivated grape seedlings, and study the effects of mulching with straw of different cadmium hyperaccumulators on growth and cadmium content of grape seedlings under cadmium stress.

2. Materials and Methods

2.1. Materials collection

The materials used in the experiment were *C. crepidioides*, *G. parviflora*, *Y. japonica* and *G. affine*. The straws were collected from the farmland (without cadmium pollution) of Chengdu Campus of Sichuan Agricultural University in March 2018. The shoot of plants was collected and washed with tap water, then washed three times with deionized water, and dried at 110 °C for 15 min, then dried to constant weight at 75 °C. The straw was cut into small sections of less than 1 cm and set aside. The cultivar of grape is “Xiahei” with cutting seedlings. The fluvo-aquic soil was collected from the farmland of Chengdu Academy of Agriculture and Forestry Sciences.

2.2. Experimental Design

The experiment was conducted in Chengdu Campus of Sichuan Agricultural University from March to May 2018. The soil was air-dried, ground and passed through a 5-mm sieve in March 2018. Each plastic pot (15 cm high, 18 cm in diameter) was filled with 3 kg of ground soil and soaking uniformly cadmium solution with 5 mg/kg cadmium (in the form of $\text{CdCl}_2 \cdot 2.5 \text{H}_2\text{O}$) for 4 weeks. All pots were watered every day to keep the soil moisture about 80%, and dug aperiodically to make soil mixed fully. In April 2018, the prepared cadmium hyperaccumulator straw was respectively mulched in the prepared cadmium contaminated soil, so that it was covered in the soil surface. Each kilogram of soil covered with 2 g straw (6 g straw in each pot), and keep the soil moist and balanced for 1 weeks. Then three uniform grape seedlings (the shoots were about 15 cm) were transplanted into each pot. The experiment consists of 5 treatments: monoculture of grape, mulching with straw of *C. crepidioides*, mulching with straw of *G. parviflora*, mulching with straw of *Y. japonica* and mulching with straw of *G. affine*. Three replicates were run for each treatment and the distance between pots was 15 cm. All pots were watered every day to keep soil moisture at 80% and exchanged the pot position aperiodically to weaken the impact of marginal effects until the plants were harvested. After 40 days, the grape seedlings were dug up and the root, stem and leaf were separated. After washed with tap water, and three times with deionized water, the tissues were dried at 110 °C for 15 min, and then dried to constant weight at 75 °C. Then the biomass (dry weight) of root, stem and leaf was measured, and the cadmium content in the tissues above was measured. The dried tissue samples were ground and sieved through a 0.149-mm mesh nylon sieve. Samples (0.50 g) were digested in $\text{HNO}_3\text{:HClO}_4$ (4:1, v/v) until the solution become transparent, then the solution was made up to 50 ml with deionized water. The solution was used to analyze the cadmium content in root, stem and leaf with iCAP 6300 ICP-mass spectrometer (Thermo Scientific, USA) [17].

2.3. Statistical Analyses

Statistical analyses were performed with SPSS 22.0 statistical software (SPSS Inc., Chicago, IL, USA). Data were analyzed with one-way analysis of variance with least significant difference at the 5% significance level.

3. Results and Discussion

3.1. Biomass of grape seedlings

Compared with monoculture, all the straw-mulch treatments increased the biomass of grape seedlings (Table 1). The biomass of root was ranked in the following order: mulching with straw of *G. parviflora* > mulching with straw of *Y. japonica* > mulching with straw of *C. crepidioides* > mulching with straw of *G. affine* > monoculture, in this order, the biomass of root of the straw-mulch treatments increased by 85.68%, 48.97%, 29.34% and 23.88% compared with monoculture, respectively. Grape

seedlings which mulching with straw of *G. parviflora* reached the highest biomass of stem, with 40.08% increased compared with monoculture, the treatment of mulching with *Y. japonica* followed, and there is no significant difference between the two treatments above ($p > 0.05$). Mulching with straw of cadmium hyperaccumulators increased the biomass of leaf of grape seedlings compared with monoculture. The biomass of leaf for the treatments of mulching with straw of *C. crepidioides* and *G. affine* had a slightly increase on the basis of monoculture ($p > 0.05$). On the contrary, the biomass of leaf for the treatments of mulching with straw of *G. parviflora* and *Y. japonica* was significantly higher than monoculture, with 17.46% and 10.54% increase, respectively, and there was no significant difference between the two treatments ($p > 0.05$). All the biomass of shoot for the straw-mulch treatments was significantly higher than monoculture ($p < 0.05$), and the biomass was ranked in the following order: mulching with straw of *G. parviflora* > mulching with straw of *Y. japonica* > mulching with straw of *C. crepidioides* > mulching with straw of *G. affine* > monoculture. According to the order, they were increased by 22.73%, 16.02%, 8.69% and 7.49% respectively compared with monoculture.

Table 1. Biomass of grape seedlings

Treatments	Root (g plant ⁻¹)	Stem (g plant ⁻¹)	Leaf (g plant ⁻¹)	Shoot (g plant ⁻¹)
M	1.411±0.006d	0.716±0.062c	2.382±0.046c	3.097±0.015d
C.cre	1.825±0.193bc	0.860±0.052b	2.506±0.041bc	3.366±0.011c
G.par	2.620±0.119a	1.003±0.065a	2.798±0.034a	3.801±0.099a
Y.jap	2.102±0.107b	0.960±0.013ab	2.633±0.070ab	3.593±0.082b
G.aff	1.748±0.076c	0.832±0.058bc	2.497±0.078bc	3.329±0.020c

Values are means ± standard error of three replicate pots. Different lowercase letters within a column indicate significant differences based on one-way analysis of variance in SPSS 22.0 followed by the least significant difference ($p < 0.05$). M = monoculture, C.cre = mulching with straw of *C. crepidioides*, G.par = mulching with straw of *G. parviflora*, Y.jap = mulching with straw of *Y. japonica*, G.aff = mulching with straw of *G. affine*.

3.2. Cadmium content in grape seedlings

Mulching with different cadmium hyperaccumulators straws had different effects on the cadmium content in grape seedlings (Table 2). Cadmium content in the root of grape seedling for the treatment of mulching with straw of *G. parviflora* was the minimum, and 2.13% ($p > 0.05$) lower than monoculture. Cadmium content in root for the other treatments was significantly higher than monoculture ($p < 0.05$), and the cadmium content for the treatment of mulching with straw of *C. crepidioides* reached the highest, with 54.96% increase compared with monoculture. All the mulch-straw treatments decreased the content of cadmium in the stem except the treatment of mulching with *G. affine* straw. The cadmium content in stem for the treatment of mulching with *G. affine* straw increased by 36.24% ($p < 0.05$) compared with monoculture. The treatment of mulching with straw of *G. parviflora* had the lowest cadmium content in stem, and decreased by 48.17% ($p < 0.05$) compared with monoculture. The trend of cadmium content in leaf and shoot was the same as that in stem. Cadmium content in leaf and shoot for the treatment of mulching with *G. affine* straw was the highest, 23.53% and 29.93% higher than monoculture ($p < 0.05$). The treatment of mulching with straw of *G. parviflora* had the lowest cadmium content in leaf and shoot, and they decreased by 17.23%, 27.82% compared with monoculture, respectively ($p < 0.05$).

Table 2. Cadmium content in grape seedlings

Treatments	Root (mg kg ⁻¹)	Stem (mg kg ⁻¹)	Leaf (mg kg ⁻¹)	Shoot (mg kg ⁻¹)
M	22.49±1.006d	0.436±0.014b	0.238±0.011b	0.284±0.016b
C.cre	34.85±0.945a	0.406±0.022b	0.219±0.013bc	0.267±0.001b
G.par	22.01±1.019d	0.226±0.017d	0.197±0.016c	0.205±0.007d
Y.jap	25.12±0.550c	0.293±0.023c	0.212±0.013bc	0.234±0.016c
G.aff	31.18±1.207b	0.594±0.024a	0.294±0.013a	0.369±0.002a

Values are means ± standard error of three replicate pots. Different lowercase letters within a column indicate significant differences based on one-way analysis of variance in SPSS 22.0 followed by the least significant difference ($p < 0.05$). M = monoculture, C.cre = mulching with straw of *C. crepidioides*, G.par = mulching with straw of *G. parviflora*, Y.jap = mulching with straw of *Y. japonica*, G.aff = mulching with straw of *G. affine*.

4. Conclusions

The experiment showed that mulching with cadmium hyperaccumulators straws could generally increase the biomass of grape seedlings. Mulching with straw of *G. parviflora* increased the biomass of grape seedlings mostly, and the biomass of root and shoot was 85.68% and 22.73% higher than monoculture, respectively. All the straw-mulch treatments increased the cadmium content in root of grape seedlings except the treatment of mulching with *G. parviflora* straw, and the cadmium content in root for the treatment of mulching with straw of *G. parviflora* was 2.13% lower than monoculture. The cadmium content in root for the treatment of mulching with straw of *C. crepidioides* reached maximum (34.85 mg kg⁻¹), increased by 54.96% compared with monoculture. Cadmium content in stem, leaf and shoot for all the straw-mulch treatments was lower than monoculture except the treatment of mulching with straw of *G. affine*. The cadmium content in stem, leaf and shoot for the treatment of mulching with straw of *G. affine* was 36.24%, 23.53% and 29.93% higher than monoculture. The cadmium content in stem, leaf and shoot for the treatment of *G. parviflora* reached minimum, decreased by 48.17%, 17.23% and 27.82% compare to monoculture, respectively. In conclusion, mulching with cadmium hyperaccumulators straw could effectively increase the biomass of grape seedlings (promote the growth of grape seedlings), and decrease the cadmium content in shoot commonly. Among the four hyperaccumulators straw, mulching with straw of *G. parviflora* worked best, which increased the root and shoot biomass mostly and decreased cadmium content in root and shoot simultaneously.

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