Effects of Mulching with Hyperaccumulator Straw on Photosynthetic Pigment Contents in Grape Seedlings under Cadmium Stress

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Abstract. To study the effects of mulching with straw of different cadmium hyperaccumulators (*Crassocephalum crepidioides*, *Galinsoga parviflora*, *Youngia japonica* and *Gnaphalium affine*) on photosynthetic pigment contents in grape seedlings was conducted by a pot experiment under cadmium stress. The results showed that mulching with straw of *C. crepidioides* and *G. parviflora* increased the content of chlorophyll *a* and total chlorophyll of grape seedlings. All the straw-mulch treatments increased the chlorophyll *b* content of grape seedlings, and the chlorophyll *a*/*b* for all the treatments had no significant difference. Except mulching with *Y. japonica* reduced the content of carotenoid, other straw-mulch treatments increased the carotenoid content of grape seedlings. Especially, mulching with *G. parviflora* significantly increased the content of chlorophyll *a*, chlorophyll *b*, total chlorophyll and carotenoid, with a increasing of 40.60%, 47.85%, 42.80% and 47.79%, respectively. In conclusion, mulching with *G. parviflora* straw could increase photosynthetic pigment contents of grape seedlings under cadmium stress.

1.Introduction

Photosynthesis is the basis of plant growth and development, chlorophyll *a* and chlorophyll *b* are important photosynthetic pigments in the chloroplasts of higher plants, which are directly related to the photosynthetic assimilation process of plants [1-2]. The ratio of chlorophyll *a*/*b* is important for the photosynthetic activity of chloroplasts and carotenoids are not only the catcher of light, but also protect chloroplasts from excess light [3-4]. Therefore, the content of photosynthetic pigments is commonly used to determine the photosynthesis capacity of plants and reflect the degree of environmental stress [5-6]. Cadmium (Cd), as a trace element ubiquitous in the soil, can inhibit photosynthesis and synthesis of chlorophyll, and then inhibit the growth of plants [8-9]. Straw returning into field is an effective way to utilize straw, which can be divided into straw mulching and straw blending into soil. Straw returning into field can promote or inhibit the growth of plants via changing the soil physical and chemical properties. Some studies have shown that applying some Cd hyperaccumulators or accumulators straw in Cd contaminated soil could increase the photosynthetic pigment contents of *Galinsoga parviflora* (Cd hyperaccumulator), and others could decrease the content of photosynthetic pigment [10-12]. Therefore, it can infer that mulching with straw of Cd hyperaccumulators could have effects on the photosynthetic characteristics of other plants. In the study, four Cd hyperaccumulators (*Crassocephalum crepidioides* [13], *Galinsoga parviflora* [14], *Youngia japonica* [15] and *Gnaphalium affine* [16]) straws were mulched on the surface of Cd-contaminated soil, then cultivated grape seedlings, and the effects of mulching with straw of different Cd hyperaccumulators on photosynthetic pigment contents of grape seedlings under Cd stress were studied.

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 Cd 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 was "summer black" 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. In March 2018, the soil was air-dried, ground and passed through a 5-mm sieve. Each plastic pot (15 cm high, 18 cm in diameter) was filled with 3 kg of ground soil and soaking uniformly Cd solution with 5 mg/kg Cd (in the form of $CdCl_2 \cdot 2.5\ H_2O$) 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 Cd hyperaccumulators straw was respectively mulched in the prepared Cd contaminated soil, so that it was covered in the soil surface. Each kilogram of soil covered 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 upper mature leaves of grape seedlings were collected to determine the contents of photosynthetic pigment (chlorophyll a, chlorophyll b and carotenoid) [17].

2.3 Statistical Analyses
Statistical analyses were performed using 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 Chlorophyll a content of grape seedlings

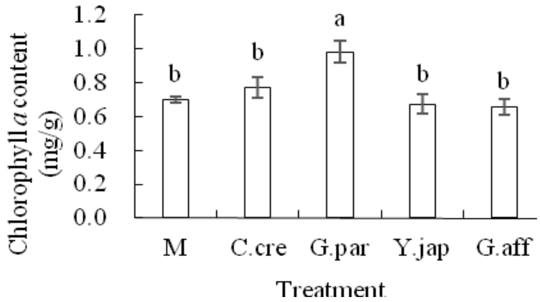

Figure 1. Chlorophyll *a* content of grape seedlings. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 22.0 followed by the least significant difference test ($p < 0.05$). M = monoculture, C.cre = mulching with straw of *C. crepidioides*, G.par = mulching with straw of *G. parviflora*, Y.jap = mulching with straw of *Y. japonica*, G.aff = mulching with straw of *G. affine*. Same as below.

The effects of mulching with straw of Cd hyperaccumulators on chlorophyll a content of grape seedlings divided into two types (Figure 1). Compared with monoculture, mulching with straw of C. crepidioides and G. parviflora increasing the chlorophyll a content of grape seedlings, the content of chlorophyll a of grape seedlings for the treatment of mulching with straw of G. parviflora was 40.60% higher than monoculture, and the chlorophyll a content of grape seedlings mulching with straw of C. crepidioides had no significantly increase ($p > 0.05$). The content of chlorophyll a for the treatments of mulching with straw of Y. japonica and G. affine decreased, but there was no significant difference from monoculture ($p > 0.05$).

3.2 Chlorophyll b content of grape seedlings

For the content of chlorophyll *b*, all the straw-mulch treatments increased the chlorophyll *b* content of grape seedlings (Figure 2). The content of chlorophyll *b* had no significant variation for all the straw-mulch treatments except mulching with *G. parviflora* straw ($p > 0.05$). Mulching with *G. parviflora* straw increasing the content of chlorophyll *b* significantly, and 47.85% higher than monoculture.

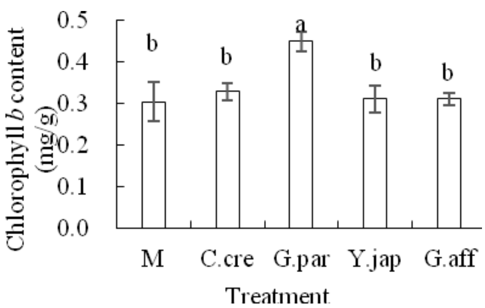

Figure 2. Chlorophyll *b* content of grape seedlings.

3.3 Total chlorophyll content of grape seedlings

The tread of total chlorophyll content of grape seedlings was the same as which of chlorophyll *a* content (Figure 3). The treatment of mulching with *G. parviflora* straw had the highest total chlorophyll content, and 42.80% higher than monoculture. Mulching with *C. crepidioides* straw increased the content of total chlorophyll of grape seedlings, but the increase was not significant ($p >$

0.05). The treatments of mulching with straw of *Y. japonica* and *G. affine* decreased the total chlorophyll content, and the decline was not significant ($p > 0.05$).

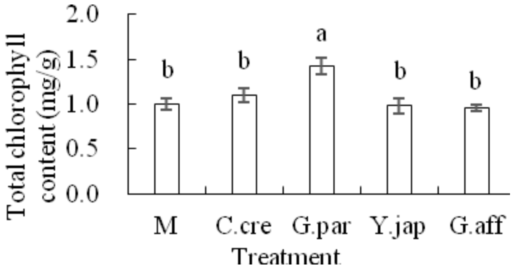

Figure 3 Total chlorophyll content of grape seedlings.

3.4 The ratio of chlorophyll a/b of grape seedlings

For the ratio of chlorophyll *a*/*b*, except the treatment of mulching with *C. crepidioides* straw increased the chlorophyll *a*/*b* ratio of grape seedlings, other treatments all reduced the chlorophyll *a*/*b* ratio of grape seedlings (Figure 4). There was no significant difference in chlorophyll *a*/*b* ratio for the treatments of mulching with these Cd hyperaccumulators straw compared with monoculture ($p >$ 0.05).

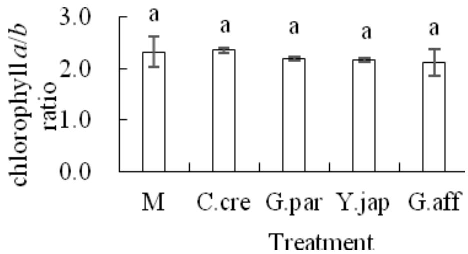

Figure 4. Chlorophyll *a*/*b* ratio of grape seedlings.

3.5 Carotenoid content of grape seedlings

For the content of carotenoid, all the straw-mulch treatments increased the carotenoid content of grape seedlings except the treatment of mulching with straw of *Y. japonica* (Figure 5). The content of carotenoid was ranked in the following order: mulching with straw of *G. parviflora* > mulching with straw of *C. crepidioides* > mulching with straw of *G. affine* > monoculture > mulching with straw of *Y. japonica.* The carotenoid content of grape seedlings for the treatment of mulching with straw of *G. parviflora, C. crepidioides* and *G. affine* successively increased by 47.79% ($p < 0.05$), 9.735% ($p > 0.05$) and 5.310% ($p > 0.05$), compared with monoculture, respectively. The carotenoid content of grape seedlings for the treatment of mulching *Y. japonica* straw was 14.16% lower than monoculture ($p > 0.05$).

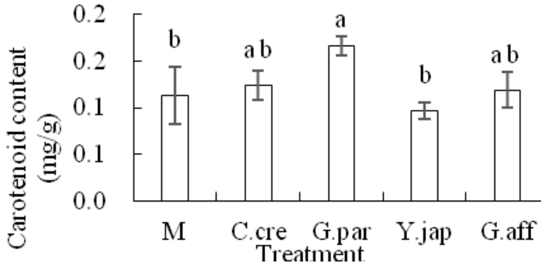

Figure 5 Carotenoid content of grape seedlings.

4.Conclusions

The experiment showed that mulching with different kinds of Cd hyperaccumulators straws had different effects on photosynthetic pigment contents of grape seedlings. Mulching with straw of *C. crepidioides* and *G. parviflora* increased the contents of chlorophyll *a* and total chlorophyll of grape seedlings, and mulching with straw of *Y. japonica* and *G. affine* decreased those of grape seedlings. Compared with monoculture, the content of chlorophyll *a* and total chlorophyll of grape seedlings for the treatment of mulching with *G. parviflora* straw were 40.60% and 42.80% higher than monoculture, respectively. The indexes above for the treatment of mulching with *C. crepidioides* straw were no obvious increase ($p > 0.05$). All the straw-mulch treatments increased the chlorophyll *b* content, but the increase was not significant except mulching with *G. parviflora* straw ($p > 0.05$). The content of chlorophyll *b* of grape seedlings for the treatment of mulching with *G. parviflora* straw was 47.85% higher than monoculture. Mulching with straw had little effect on the ratio of chlorophyll *a*/*b*, the chlorophyll *a*/*b* ratio for all the treatments had no significant difference ($p > 0.05$). Mulching with straw of *C. crepidioides*, *G. parviflora* and *G. affine* increased the content of carotenoid, and mulching with *Y. japonica* reduced it. The carotenoid content of grape seedlings for the treatment of mulching *G. parviflora* straw was 47.79% higher than monoculture ($p < 0.05$) and the content of it for the treatment of mulching *Y. japonica* straw was 14.16% lower than monoculture ($p > 0.05$). Therefore, mulching with *G. parviflora* straw could increase the photosynthetic pigment contents of grape seedlings significantly, and promote the growth of grape seedlings under Cd stress.

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