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Effects of Grape Seedlings Intercropping with Bidens Species on Different Fractions of Cadmium Content in Soil

Lisha Zhong[1,a], Liying Ouyang[2,b], Ming'an Liao[1,c] and Lijin Lin[3,d*]

[1]College of Horticulture, Sichuan Agricultural University, Chengdu, Sichuan, China

[2]Department of Modern Agriculture, Chendu Agricultural College, Chengdu, Sichuan, China

[3]Institute of Pomology and Olericulture, Sichuan Agricultural University, Chengdu, Sichuan, China

[a]645627089@qq.com, [b]24983471@qq.com, [c]lman@sicau.edu.cn, [d]llj800924@qq.com

*Corresponding author. Lisha Zhong and Liying Ouyang contributed equally to this work.

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Abstract: The bioavailability of cadmium (Cd) is closely related to its presence in soil, in the experiment, grape was intercropped with four Bidens species (*Bidens bipinnata*, *Bidens pilosa*, *Bidens parviflora* and *Bidens biternata*) to study the effects of grape seedlings intercropping with Bidens species on the fractions of Cd content in soil. The results showed that: grape intercropping with different Bidens species had different effects on the fractions of Cd. Intercropping with *B. biternata* increased the exchangeable Cd and decreased the residual Cd. But intercropping with the other two Bidens species (*B. bipinnata* and *B. parviflora*) had a little beneficial effect on reducing the bioavailability of Cd. Especially, in the treatment of intercropping with *B. pilosa*, the exchangeable Cd was 9.38% lower than the monoculture of grape and the residual Cd in soil was 91.67% higher than the monoculture. Therefore, *B. pilosa* could be the best choice to decrease the bioavailability of Cd when intercropping with grape.

1. Introduction

Cadmium (Cd) is a kind of heavy mental, which has high toxicity to plants. According to Tessier, the Cd in soil can be divided into five fractions: exchangeable, bound to carbonates, bound to Fe-Mn oxides, bound to organic matter, and residual [1]. The exchangeable Cd has a relative high bioavailability and easily absorbed by plants. Residual Cd is a strongly bound form and hard to be absorbed by plants. Although the bioavailability of Cd bound to carbonates, bound to Fe-Mn oxides and bound to organic matter relatively a little low, they are in dynamic equilibrium with the exchangeable state, and continuous supply source for exchangeable Cd [2]. Therefore, the presence of heavy metal elements in soil is the key parameter to measure its environmental effects [3-4]. Studies have shown that plants intercropping with Cd-accumulators can effectively reduce the absorption of Cd [5-6]. We guessed whether intercropping reduces the absorption of Cd of plants by changing the fractions of Cd in the soil, so it is necessary to study the effect on five fractions of Cd in soil in the intercropping mode. The Bidens species has strong tolerance and accumulation ability to Cd and belongs to Cd-accumulators [7-11]. In the study, four Bidens species (*Bidens bipinnata*, *Bidens pilosa*, *Bidens parviflora* and *Bidens biternata*) were used to intercrop with grape seedlings under Cd stress, and the fractions of Cd in soil were measured. The aim of the study was to explore the effects on five fractions of Cd content in soil of grape seedlings intercropping with Bidens species and then selected the best intercropping treatment for reducing the bioavailability of Cd.

2. Materials and Methods

Materials. The seeds of four Bidens species and the fluvo-aquic soil samples were collected from the farmland surrounding Chengdu Campus of Sichuan Agricultural University in April, 2016. The cultivar of grape is Kyoho with cutting seedlings.

Experimental Design. The experiment was conducted in Chengdu Campus of Sichuan Agricultural

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University from April to July 2016. In April, the soil was air-dried, ground and passed through a 6.72-mm sieve. Each plastic pot (21 cm high, 20 cm in diameter) was filled with 3kg of ground soil mixed with 5 mg/kg Cd in solution (in the form of $CdCl_2 \cdot 2.5H_2O$) for 4 weeks. All pots were watered each day to keep the soil moisture about 80%, and dug aperiodically to make soil mixed fully. In May 2016, three uniform seedlings (the shoots were about 15 cm) of grape were transplanted into each pot for monoculture and two of them for intercropping, respectively. Then one uniform seedlings of each Bidens species with two pairs of true leaves were transplanted into each pot for intercropping (the seeds were put in the climate chamber to raise seedlings). The experiment consists of 5 treatments: monoculture of grape, grape intercropped with *B. bipinnata*, grape intercropped with *B. pilosa*, grape intercropped with *B. parviflora* and grape intercropped with *B. biternata*. Three replicates were run for each treatment, and the experiment pots were arranged in a completely randomized design.

After 60 days, the soil from the rhizosphere in the corresponding pot was collected immediately when the plants were collected. All the soil samples were air-dried at room temperature then ground to pass through a 1-mm nylon sieve for analysis of five fractions of Cd. Soil samples (1.0 g) were digested with 5:1 (v:v) HNO_3:$HClO_4$ and measured by novAA 400P flame atomic absorption spectrophotometer (Analytik Jena, Germany) [12].

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.

3. Results and Discussion

The Content of Exchangeable Cadmium. The content of exchangeable Cd in soil had a little decline after intercropping for the treatment of grape intercropped with *B. bipinnata*, grape intercropped with *B. pilosa*, grape intercropped with *B. parviflora,* but the effect was not significant. On the contrary, grape intercropped with *B. biternata* increased the exchangeable Cd in soil (Fig. 1). Sort by the content of exchangeable Cd from highest to lowest were: grape intercropped with *B. biternata* > monoculture of grape ≈ grape intercropped with *B. parviflora* ≈ grape intercropped with *B. bipinnata* ≈ grape intercropped with *B. pilosa.* The content of exchangeable Cd in the treatment of intercropping with *B. pilosa* was 9.38% ($p < 0.05$) lower than the monoculture.

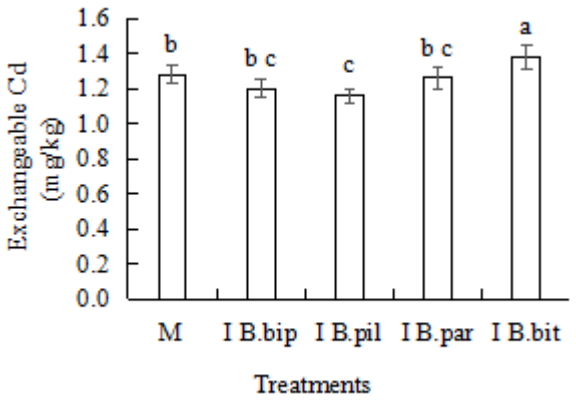

Fig. 1 The content of exchangeable Cd in soil. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test ($p < 0.05$). M = monoculture, I B. bip = intercropping with *B. bipinnata*, I B. pil = intercropping with *B. pilosa*, I B. par = intercropping with *B. parviflora*, I B. bit = intercropping with *B. biternata*.

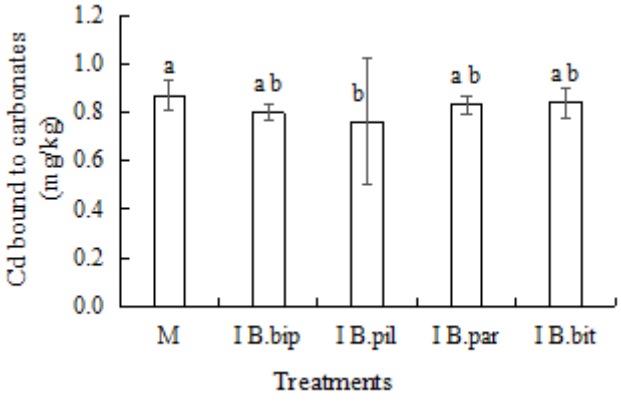

Fig. 2 The content of Cd bound to carbonates in soil. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test ($p < 0.05$). M = monoculture, I B. bip = intercropping with *B. bipinnata*, I B. pil = intercropping with *B. pilosa*, I B. par = intercropping with *B. parviflora*, I B. bit = intercropping with *B. biternata*.

The Content of Cadmium Bound to Carbonates. Intercorpping had a little contribution to the decline of Cd bound to carbonates. The content of Cd bound to carbonates of all the intercropping treatments were lower than monoculture, but the content of Cd bound to carbonates for the treatments of intercropping with *B. biternata, B. parviflora, B. bipinnata* had no significance difference (Fig. 2). Intercropping with *B. pilosa* reduced the Cd bound to carbonates in soil obviously, and 12.64% ($p < 0.05$) lower than monoculture of grape.

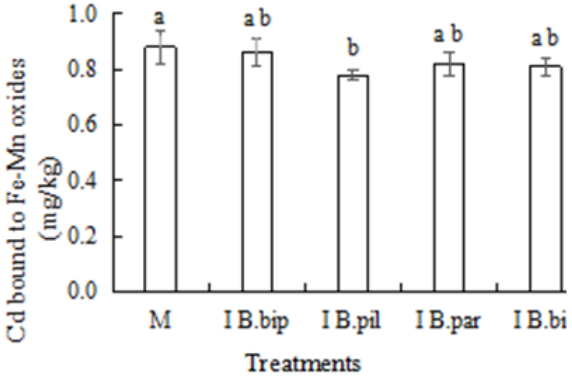

Fig. 3 The content of Cd bound to Fe-Mn oxides in soil. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test ($p < 0.05$). M = monoculture, I B. bip = intercropping with *B. bipinnata*, I B. pil = intercropping with *B. pilosa*, I B. par = intercropping with *B. parviflora*, I B. bit = intercropping with *B. biternata*.

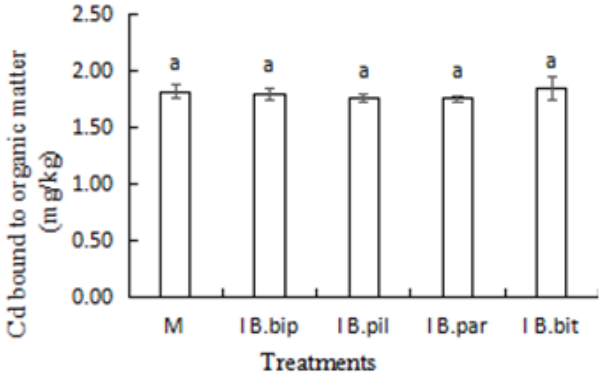

Fig. 4 The content of Cd bound to organic matter in soil. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test ($p < 0.05$). M = monoculture, I B. bip = intercropping with *B. bipinnata*, I B. pil = intercropping with *B. pilosa*, I B. par = intercropping with *B. parviflora*, I B. bit = intercropping with *B. biternata*.

The Content of Cadmium Bound to Fe-Mn Oxides. Intercropping can partially reduce Cd bound to Fe-Mn oxides in soil (Fig. 3). All the Cd bound to Fe-Mn of intercropping treatments were lower than the monoculture but the differences did not reach significant levels except the treatment of intercropping with *B. pilosa*, the Cd bound to Fe-Mn oxides in soil when grape intercropped with *B. pilosa* was 11.36% ($p < 0.05$) lower than monoculture of grape.

The Content of Cadmium Bound to Organic Matter. Intercropping with *B. biternata* increased the Cd bound to organic matter in soil compared to monoculture of grape, and the the rest intercropping treatments declined the Cd bound to organic matter in soil even the differences was not significant (Fig. 4).

The Content of Residual Cadmium. The content of residual Cd of treatment which intercropping with *B. biternata* was a little lower than the monoculture but the difference was not significant (Fig. 5). On the contrary, intercropping with *B. bipinnata*, *B. pilosa*, and *B. parviflora* increased the content of residual Cd in soil obviously and the three treatments successively increased by 50%, 91.67% and 41.67% ($p < 0.05$) compared to the monoculture, respectively.

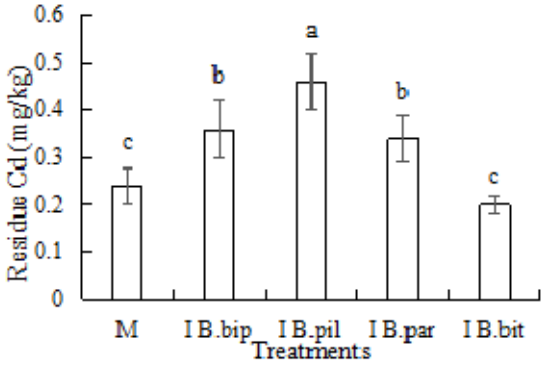

Fig. 5 The content of residual Cd in soil. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test ($p < 0.05$). M = monoculture, I B. bip = intercropping with *B. bipinnata*, I B. pil = intercropping with *B. pilosa*, I B. par = intercropping with *B. parviflora*, I B. bit = intercropping with *B. biternata*.

4. Conclusions

In the experiment, intercropping wiht different Bidens species had different effects on the fractions of Cd in soil. Intercropping with *B. biternata* increased the exchangeable Cd and decreased the residual Cd in soil. The other two intercropping treatments (intercropping with *B. bipinnata* and *B. parviflora*) had some beneficial effects on declining the bioavailability of Cd. In the treatments, intercropping with *B. pilosa* had the best effect, the exchangeable Cd was 9.38% ($p < 0.05$) lower than the monoculture and the residual Cd in soil was 91.67% ($p < 0.05$) higher than the monoculture. In conclusion, it was not suitable for *B. biternata* to intercropping with grape for reducing the bioavailability of Cd. Intercropping with *B. bipinnata*, *B. parviflora* and *B. pilosa* can reduce the bioavailability of Cd, and grape intercropping with *B. pilosa* can get the best effect on reducing the bioavailability of Cd. Therefore, intercropping with *B. pilosa* could benefit for the decline of bioavailability of Cd.

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