Effects of Grape Seedlings Intercropping with Floricultural Accumulator Plants on Different Fractions of Cadmium Content in Soil

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Abstract: The total amount of cadmium (Cd) in soil reflects the degree of pollution of the soil, but the bioavailability of Cd is mainly reflected by various fractions of it. In the experiment, four floricultural accumulator plants (*Helianthus annuus*, *Cosmos sulphureus*, *Cosmos bipinnata* and *Impatiens balsamina*) were used to intercrop with grape seedlings. The fractions of Cd in soil were studied after intercropping and the results showed that: The content of exchangeable Cd for the treatment of intercropping with *H. annuus* was 11.73% higher than the monoculture. The treatments of intercropping with *C. bipinnata* and *I. balsamina* can decrease the bioavailability of Cd significantly. Therefore, *C. bipinnata* and *I. balsamina* were suitable to intercrop with grape seedlings for the purpose of controlling Cd pollution in soil.

1. Introduction

Cadmium (Cd) as the 6th toxic substance harmful to human health by the American Management Council (ATSDR) has become the major heavy metal pollutant in agricultural products in China [1]. The total amount of heavy metals in soil reflects the degree of pollution of the soil, but the bioavailability of heavy metals is mainly reflected by various fractions of heavy metals in soil [2]. There are five fractions of Cd (exchangeable, bound carbonates, bound to Fe-Mn oxides, bound to organic matter and residual) in soil according to Tessier [3]. The exchangeable Cd is the most active fraction and easily absorbed by plant, the residual Cd is inert fraction and hardily to be absorbed. Cd bound to carbonates and Cd bound to Fe-Mn oxides are sensible to the varieties of pH, Eh in soil and easily reentered to soil [4]. The organic matter in soil can adsorb exchangeable Cd and convert it into Cd bound to organic matter to reduce the bioavailability of it [5]. Intercropping can adjust the basic properties of soil and change the rhizosphere environment, which can direct or indirect affect the fractions and the bioavailability of Cd in soil, then affect the absorption of Cd of the plant [6, 7]. Therefore, the governance of Cd pollution can begin by reducing the bioavailability of Cd via intercropping. Different intercropping combination could lead to different changes to the bioavailability of Cd. In the study, we used four floricultural accumulator plants (*Helianthus annuus* [8], *Cosmos sulphureus* [9], *Cosmos bipinnata* [10] and *Impatiens balsamina* [11]) to intercrop with grape seedlings, and research the effects on the fractions of Cd under the intercropping patterns then to find the suitable plant which can reduce the bioavailability of Cd in soil.

2. Materials and Methods

Materials. The seeds of four floricultural accumulator plants were collected from the farmland surrounding Chengdu Campus of Sichuan Agricultural University in March, 2016. The cultivar of grape is Kyoho cutting seedlings. The fluvo-aquic soil samples were collected from the experimental filed of Chengdu Agricultural and Forestry Academy in March, 2016.

Experimental Design. The experiment was conducted in Chengdu Campus of Sichuan Agricultural University from March to July, 2016. In March, the soil was air-dried, ground and passed through a 6.72-mm sieve, then soaked it in the solution with 5 mg/kg Cd (in the form of $CdCl_2 \cdot 2.5H_2O$), and keeping the soil in the stage for 4 weeks to make the soil mixed well with Cd. In April, mixed the soil again and then put 3 kg soil into every pot (21 cm high, 20 cm in diameter). Three uniform seedlings (25 cm in height) of grape were transplanted into each pot for monoculture and two of them for intercropping, respectively. One uniform seedlings of each floricultural accumulator plants (3 cm in height, and with 2 true leaves) were transplanted into each pot for intercropping (the seeds were put in the climate chamber to raise seedlings in March). The experiment consists of 5 treatments: monoculture of grape, grape intercropped with *H. annuus*, grape intercropped with *C. sulphureus*, grape intercropped with *C. bipinnata* and grape intercropped with *I. balsamina*. 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 while collecting the plant materials. All the soil samples were air-dried at room temperature then ground to pass through a 1-mm nylon sieve for analysis 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. Intercropping with different floricultural accumulator plants had different effects on the content of exchangeable Cd (Fig. 1). Intercropping with *H. annuus* and *C. sulphureus* increased the content of exchangeable Cd compared to monoculture of grape, and they were 11.73% ($p > 0.05$), 9.18% ($p > 0.05$) higher than the monoculture, respectively. On the contrary, intercropping with *C. bipinnata* and *I. balsamina* can decrease the content of exchangeable Cd. The content of exchangeable Cd in the two intercropping patterns were 8.67% ($p > 0.05$) and 3.06% ($p > 0.05$) lower than the monoculture, respectively.

The Content of Cadmium Bound to Carbonates. The intercropping patterns decreased the content of Cd bound to carbonates except the treatment of intercropping with *I. balsamina* (Fig. 2), but the increase or decrease was not significant. The content from highest to lowest was ranked as grape intercropping with *I. balsamina* > monoculture of grape > grape intercropping with *H. annuus* > grape intercropping with *C. bipinnata* > grape intercropping with *C. sulphureus.*

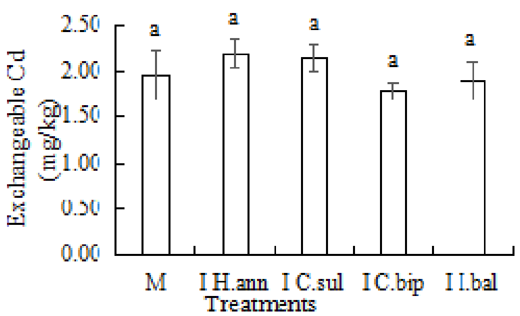

Fig. 1 The content of exchangeable Cd in soil. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test ($p < 0.05$). M = monoculture, I H. ann = intercropping with *H. annuus*, I C. sul = intercropping with *C. sulphureus*, I C. bip = intercropping with *C. bipinnata*, I I. bal = intercropping with *I. balsamina*.

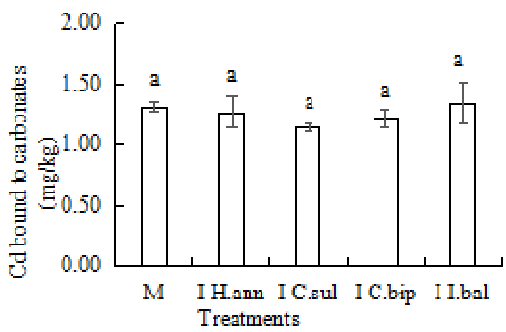

Fig. 2 The content of Cd bound to carbonates in soil. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test ($p < 0.05$). M = monoculture, I H. ann = intercropping with *H. annuus*, I C. sul = intercropping with *C. sulphureus*, I C. bip = intercropping with *C. bipinnata*, I I. bal = intercropping with *I. balsamina*.

The Content of Cadmium Bound to Fe-Mn Oxides. All the intercropping treatments increased the content of Cd bound to Fe- Mn oxides (Fig. 3). The content of Cd bound to Fe- Mn oxides for the treatment of intercropping with *H. annuus* was 23.53% ($p < 0.05$) higher than monoculture and the other three treatments had no significant increase compared to monoculture.

The Content of Cadmium Bound to Organic Matter. Intercropping had a beneficial effect on increasing the content of Cd bound to organic matter (Fig. 4). All the intercropping patterns increased the content of Cd bound to organic matter and the treatment of intercropping with *C. bipinnata* had the best effect with 11.88% ($p > 0.05$) higher than the monoculture.

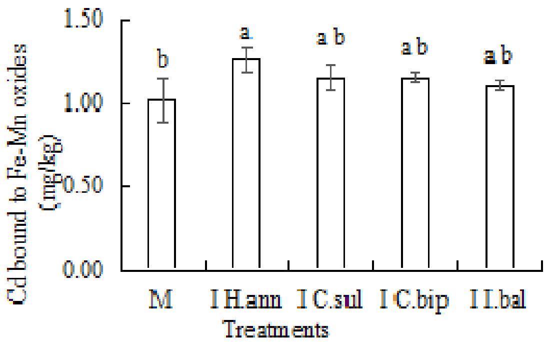

Fig. 3 The content of Cd bound to Fe-Mn oxides in soil. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test ($p < 0.05$). M = monoculture, I H. ann = intercropping with *H. annuus*, I C. sul = intercropping with *C. sulphureus*, I C. bip = intercropping with *C. bipinnata*, I I. bal = intercropping with *I. balsamina*.

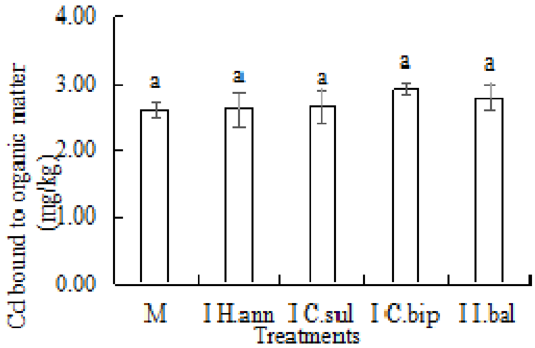

Fig. 4 The content of Cd bound to organic matter in soil. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test ($p < 0.05$). M = monoculture, I H. ann = intercropping with *H. annuus*, I C. sul = intercropping with *C. sulphureus*, I C. bip = intercropping with *C. bipinnata*, I I. bal = intercropping with *I. balsamina*.

The Content of Residual Cadmium. All the intercropping patterns increased the content of residual Cd in soil obviously. Sorting the content of residual Cd of each treatment from highest to lowest: intercropping with *I. balsamina* > intercropping with *C. bipinnata* > intercropping with *H. annuus* > intercropping with *C. sulphureus* (Fig. 5). In particular, the content of residual Cd for the treatments of intercropping with *I. balsamina* and *C. bipinnata* were 44.12% ($p < 0.05$) and 35.29% ($p < 0.05$) higher than the monoculture.

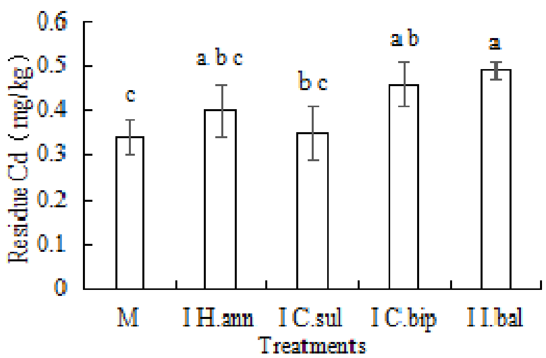

Fig. 5 The content of residual Cd in soil. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test ($p < 0.05$). M = monoculture, I H. ann = intercropping with *H. annuus*, I C. sul = intercropping with *C. sulphureus*, I C. bip = intercropping with *C. bipinnata*, I I. bal = intercropping with *I. balsamina*.

4. Conclusions

According to the experiment, we got the following conclusions: Intercropping with different floricultural accumulator plants had different effects on the fractions of Cd in soil. Intercropping with *H. annuus* increased the content of exchangeable Cd in soil significantly (11.73% higher than the monoculture). Grape intercropping with *C. bipinnata* and *I. balsamina* decreased the content of exchangeable Cd and increased the content of Cd bound to organic matter and residual Cd, and then the bioavailability of Cd decreased. Therefore, *H. annuus* was not suitable to intercrop with grape seedlings for the purpose of controlling the Cd pollution in soil. *C. bipinnata* and *I. balsamina* can be used in vineyards to decrease the bioavailability of Cd and protect the grape from Cd pollution.

Acknowledgements

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References

[1] B. Song, D. Gao, T.B. Chen, Z.C. Huang, Y.M. Zhen, M. Lei, G.D. Zhen, J. Yang and X.Y. Liao: Journal of Environmental Science Vol. 26(2006), p. 1343.

[2] Z.J. Yang, Z.G. Zhang, J.Y. Cao, J. Liu and A.M. Han: Journal of Huaiyin Institute of Technology Vol. 3(2003), p. 85.

[3] A. Tessier, P.G.C. Campbell, M. Bisson: Analytical Chemistry Vol. 51(1979), p. 844.

[4] J.L. Li, H.M. Song: Environmental Science Trends Vol. 1(2003), p. 24.

[5] S. Gao, J.B. Chen, G. Wang: Plant Nutrition and Fertilizer Science Vol. 1(2003), p. 102.

[6] G.C. Daellenbach, P.C. Kerridge, M.S. Wolfe: Agricultural Ecosystems and Environment Vol. 105(2005), p. 595.

[7] G. Agegnegu, A. Ghizaw, W. Sinebo: European Journal of Agronomy Vol. 25(2006), p. 202.

[8] J. Zou, P. Xu, X. Lu, W. Jang and D. Liu: Pakistan Journal of Botany Vol. 40(2008), p.759.

[9] L.J. Lin, Q.Q. Ma, J. Shi, J. He, C.C. Zhong, J.J. Huang, K. Wen and M.A. Liao: Journal of Soil and Water Conservation Vol. 3(2016), p. 141.

[10] J.J. Huang, Z.B. Yang, J.H. Li, M.A. Liao, L.J. Lin, J. Wang, Y.X. Yang, D. Liang and H. Xia: Chemistry and Ecology Vol. 33(2017), p. 1.

[11] Z.F. Wang, K.W. Huang, H.S. Lian and L.J. Lin: Northern Horticulture Vol. 7(2018), p. 66.

[12] J.C. Ai, N. Li and N. Wang: Journal of Agro-Environment Science Vol. 32(2013), p.491.