

Effects of Intercropping Density of *Galinsoga parviflora* on Cadmium Accumulation of Soybean

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Abstract: The effects of intercropping different density (1, 2, 3, 4 and 5) of cadmium (Cd) hyperaccumulator *Galinsoga parviflora* on cadmium accumulation of soybean were investigated through pot experiment. The results showed that intercropping with 1 *G. parviflora* seedling increased biomass of soybean compared with monoculture, and decreased when intercropping with 2, 3, 4 and 5 *G. parviflora* seedlings. Intercropping with different density of *G. parviflora* decreased Cd content in soybean compared with monoculture, and the more number of *G. parviflora*, the lower Cd content in soybean. When the density was not more than 3, intercropping with soybean increased biomass of *G. parviflora*, and decreased Cd content in *G. parviflora*. Intercropping with soybean increased Cd extraction by *G. parviflora*. Therefore, the best density of *G. parviflora* to intercropping with soybean was 1, which could be used in the Cd-contaminated soil for the phytoremediation.

Introduction

In agricultural production, the intercropping is used improve soil nutrients, water and light resources using efficiency of crop, and thus improve the yield and quality of crop [1-2]. Under heavy metal contamination conditions, when roots of two plant species close or touch, the phenomenon of "rhizosphere talk" could produce between two plant spaces, which could promote or inhibit plant growth and heavy metal accumulation [3-5]. When hyperaccumulator *Sedum alfredii* intercrops with common plants maize and ryegrass respectively, the Zinc (Zn) accumulation in *S. alfredii* increase significantly, and cadmium (Cd) and Zn contents in maize and ryegrass reduce significantly [6]. The other studies have the same results [7-8]. *Galinsoga parviflora* is a cadmium (Cd) hyperaccumulator [9], and soybean is an important common crop. To decrease the Cd content in soybean that growing in Cd-contaminated soil, the effects of intercropping different density of Cd-hyperaccumulator *G. parviflora* on Cd accumulation of soybean were investigated in this study. The aim of the study was to screen intercropping density of *G. parviflora* which could decrease Cd content in soybean and keep yield of soybean, and provide a reference for other crops.

Materials and Method

Materials. The inceptisol soil samples were collected from Ya'an campus farm of the Sichuan Agricultural University (29°59'N, 102°59'E), China, in March 2014. The basic properties of the soil were the same as reference [9], and the total Cd content was 0.101 mg/kg. *G. parviflora* seedlings with two pairs of euphyllas were collected from the Ya'an campus farm (from uncontaminated soil) in April 2014.

Experimental Design. The experiment was conducted at the Ya'an campus farm from March to Jun in 2014. The soil samples were air-dried and passed through a 5-mm sieve. Three kilograms of the air-dried soil was weighed into each polyethylene pot (15 cm high, 18 cm in diameter). Cd was added to soils as CdCl₂·2.5H₂O at 10 mg/kg. The soils were mixed immediately and again after 4 weeks, during which soil moisture was kept at 80%. Two uniform seedlings of soybean with one euphylla and corresponding density of *G. parviflora* seedling were transplanted into each pot. The density was 0

(monoculture), 1, 2, 3, 4 and 5 seedlings of *G. parviflora*, and each treatment was replicated five times using a completely randomized design with 10-cm spacing between pots. The soil moisture content was maintained at 80% of field capacity from the time the plants were transplanted into the pots until the time the plants were harvested.

Sample Analysis. One month (after 30 d) later, the plants were gently removed from the soil. The roots and shoots of *G. parviflora* and soybean were harvested and washed with tap water. The roots were immersed in 10 mM/L HCl for 10 min to remove Cd adhering to the root surface. Then, the treatments and analyses of plants were described as in reference [9].

Statistical Analyses. Statistical analyses were performed using SPSS 13.0 statistical software (IBM, Chicago, IL, USA). Data were analyzed by one-way analysis of variance with least significant difference at a 5% confidence level.

Results and Discussion

Biomass of Soybean. After intercropping with *G. parviflora* seedling, the biomass of soybean was different from monoculture (Fig. 1 A, B). When intercropping with 1 *G. parviflora* seedling, the root biomass of soybean increased, which increased by 9.40% ($p < 0.05$) compared with monoculture (Fig. 1 A), indicating that there would be a balance between *G. parviflora* and soybean which could promote soybean growth. However, when intercropping with 2, 3, 4 and 5 *G. parviflora* seedlings, the biomasses of soybean were decreased, which decreased by 19.91% ($p < 0.05$), 30.77% ($p < 0.05$), 37.61% ($p < 0.05$) and 40.64% ($p < 0.05$) respectively, compared with monoculture. These results showed that with the density increase of *G. parviflora*, the inhibition of *G. parviflora* to soybean was strong. As farmland weed, *G. parviflora* had strong competitiveness [9-10], and higher density made more competitiveness. The same as root biomass, the shoot biomass of soybean increased when intercropping with 1 *G. parviflora* seedling, and decreased when intercropping with 2, 3, 4 and 5 *G. parviflora* seedlings compared with monoculture (Fig. 1 B). The shoot biomass of soybean increased by 1.85% ($p > 0.05$) when intercropping with 1 *G. parviflora* seedling, and decreased by 8.62% ($p > 0.05$), 30.15% ($p < 0.05$), 39.08% ($p < 0.05$) and 48.92% ($p < 0.05$) when intercropping with 2, 3, 4 and 5 *G. parviflora* seedlings, respectively, compared with monoculture. So, intercropping with 1 *G. parviflora* seedling was benefit to promoting soybean growth.

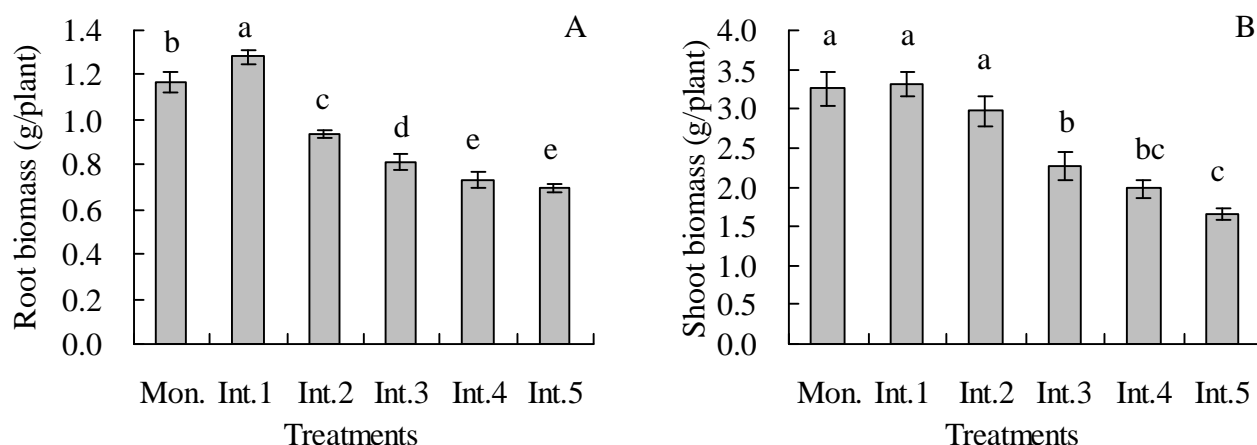


Fig. 1 Effects of intercropping density of *G. parviflora* on biomass of soybean. A = Root biomass, B = Shoot biomass. Mon. = monoculture, Int.1 = Intercropping with 1 *G. parviflora* seedling, Int.2 = Intercropping with 2 *G. parviflora* seedlings, Int.3 = Intercropping with 3 *G. parviflora* seedlings, Int.4 = Intercropping with 4 *G. parviflora* seedlings, Int.5 = Intercropping with 5 *G. parviflora* seedlings.

Cd Content in Soybean. When intercropping with *G. parviflora*, the Cd contents in roots and shoots of soybean decreased compared with monoculture (Fig. 2 A, B). Compared with monoculture, the Cd content in roots of soybean decreased by 25.36% ($p < 0.05$), 40.12% ($p < 0.05$), 45.39% ($p < 0.05$), 48.92% ($p < 0.05$) and 50.15% ($p < 0.05$) when intercropping with 1, 2, 3, 4 and 5 *G. parviflora* seedlings, respectively.

0.05), 48.65% ($p < 0.05$) and 60.59% ($p < 0.05$) when intercropping with 1, 2, 3, 4 and 5 *G. parviflora* seedlings, respectively (Fig. 2 A). The Cd content in shoots of soybean decreased by 28.20% ($p < 0.05$), 30.82% ($p < 0.05$), 38.26% ($p < 0.05$), 45.49% ($p < 0.05$) and 50.21% ($p < 0.05$) when intercropping with 1, 2, 3, 4 and 5 *G. parviflora* seedlings, respectively, compared with monoculture (Fig. 2 B). As Cd-hyperaccumulator, *G. parviflora* has strong absorption ability to soil Cd, and the number of *G. parviflora* greater in unit area, the more Cd was absorbed, which is consistent with other studies [11-12].

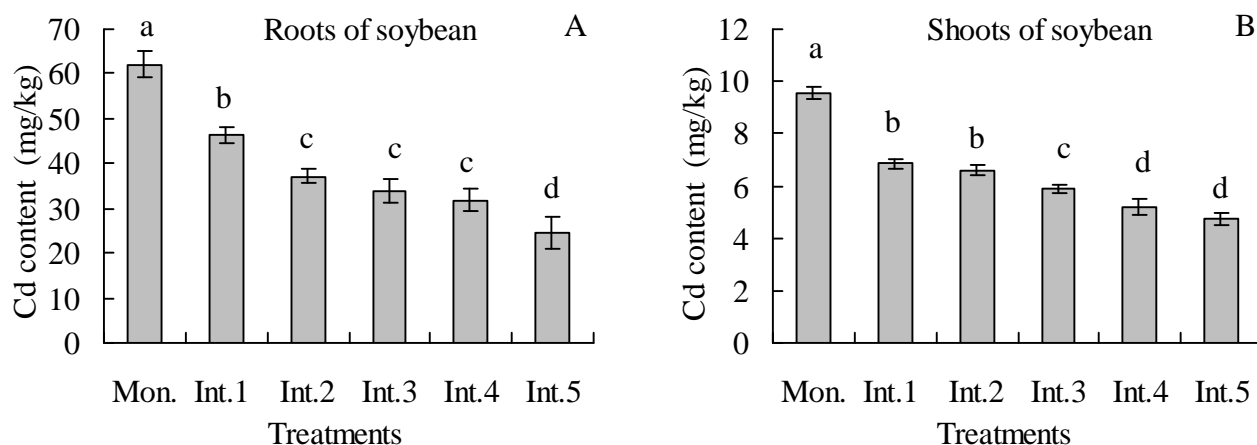


Fig. 2 Effects of intercropping density of *G. parviflora* on Cd content in soybean. A = Root biomass, B = Shoot biomass. Mon. = monoculture, Int.1 = Intercropping with 1 *G. parviflora* seedling, Int.2 = Intercropping with 2 *G. parviflora* seedlings, Int.3 = Intercropping with 3 *G. parviflora* seedlings, Int.4 = Intercropping with 4 *G. parviflora* seedlings, Int.5 = Intercropping with 5 *G. parviflora* seedlings.

Cd Accumulation of *G. parviflora*. After intercropping with soybean, with the density increasing, the root and shoot biomasses of *G. parviflora* increased when the density was not more than 3, and decreased when the density was higher than 3 (Table 1). The Cd contents in roots and shoots of *G. parviflora* decreased when the density was not more than 3, and decreased when the density was higher than 3 with the density increase of *G. parviflora*, (Table 1). The Cd content in roots of *G. parviflora* was ranked as: 5 *G. parviflora* > 1 *G. parviflora* > 2 *G. parviflora* > 4 *G. parviflora* > 3 *G. parviflora*, and the Cd content in shoots of *G. parviflora* was 5 *G. parviflora* > 4 *G. parviflora* > 1 *G. parviflora* > 2 *G. parviflora* > 3 *G. parviflora*. With the increase of density, the Cd exaction by roots of *G. parviflora* increased, and the Cd exaction by shoots of *G. parviflora* increased when the density was not more than 4 (Table 1). The Cd exaction by roots of *G. parviflora* was ranked as: 5 *G. parviflora* > 4 *G. parviflora* > 3 *G. parviflora* > 2 *G. parviflora* > 1 *G. parviflora*, and the Cd exaction by shoots of *G. parviflora* was 4 *G. parviflora* > 5 *G. parviflora* > 3 *G. parviflora* > 2 *G. parviflora* > 1 *G. parviflora*. The maximum of Cd extraction by shoots was 469.81 $\mu\text{g}/\text{pot}$. Therefore, the density of 4 *G. parviflora* seedlings intercropping with soybean could remediate soil Cd effectively.

Table 1 Effects of intercropping with soybean on Cd accumulation of *G. parviflora*

| Treatments | Biomass (g/plant) | | Cd content (mg/kg) | | Cd extraction ($\mu\text{g}/\text{pot}$) | |
|------------------------|-------------------|-------------------|--------------------|--------------------|--|--------------------|
| | Roots | Shoots | Roots | Shoots | Roots | Shoots |
| 1 <i>G. parviflora</i> | 1.58 \pm 0.04b | 3.65 \pm 0.21b | 18.58 \pm 0.59ab | 26.30 \pm 0.99bc | 29.36 \pm 0.15d | 96.00 \pm 1.96e |
| 2 <i>G. parviflora</i> | 1.85 \pm 0.10a | 4.15 \pm 0.24ab | 17.55 \pm 0.64ab | 24.31 \pm 1.12c | 64.94 \pm 1.12c | 201.77 \pm 2.42d |
| 3 <i>G. parviflora</i> | 1.83 \pm 0.06a | 4.43 \pm 0.33a | 15.23 \pm 1.09c | 23.39 \pm 1.42c | 83.61 \pm 3.39b | 310.85 \pm 3.84c |
| 4 <i>G. parviflora</i> | 1.72 \pm 0.13ab | 4.01 \pm 0.08ab | 16.58 \pm 0.59bc | 29.29 \pm 1.71ab | 114.07 \pm 4.35a | 469.81 \pm 7.51a |
| 5 <i>G. parviflora</i> | 1.24 \pm 0.08c | 2.64 \pm 0.19c | 18.99 \pm 0.81a | 32.30 \pm 2.40a | 117.74 \pm 3.06a | 426.36 \pm 0.24b |

Conclusions

Intercropping with 1 *G. parviflora* seedling increased biomass of soybean compared with monoculture, and decreased when intercropping with 2, 3, 4 and 5 *G. parviflora* seedlings. Intercropping with different density of *G. parviflora* decreased Cd content in soybean compared with monoculture, and the more number of *G. parviflora*, the lower Cd content in soybean. When the density was not more than 3, intercropping with soybean increased biomass of *G. parviflora*, and decreased Cd content in *G. parviflora*. Intercropping with soybean increased Cd extraction by *G. parviflora*, and the maximum of Cd extraction by shoots of *G. parviflora* was at the density of *G. parviflora*. Therefore, the best density of *G. parviflora* to intercropping with soybean was 1.

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