Intercropping Different Density of Galinsoga parviflora Can Increase Cadmium Accumulation in Radish

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Abstract: A pot experiment was conducted to study the effects of intercropping density different density (1, 2, 3, 4 and 5) of cadmium (Cd) hyperaccumulator *Galinsoga parviflora* on Cd accumulation of radish. Intercropping different densities with *G. parviflora* decreased the growth of radish, and increased cadmium content in radish. After intercropping with *G. parviflora*, the Cd content in radish increased when the density of *G. parviflora* was not more than 3, and decreased when the density of *G. parviflora* was higher than 3. When the density was not more than 3, intercropping with radish increased biomass of *G. parviflora*, and decreased when the density was higher than 3. Intercropping with radish increased Cd content in *G. parviflora*. With the increase of density, the Cd exaction by roots of *G. parviflora* increased when the density was not more than 4, and decreased when the density was higher than 4. Therefore, in the Cd-contaminated soil, intercropping with *G. parviflora* could not be suitable for radish production.

Introduction

With the development of industrial and agricultural, the heavy metal concentration in soil increases, and the soil is contaminated more seriously [1]. When the heavy metal absorbs by plant and accumulates in plant body, and then accumulates in human body through the food chain, which threats the health of human [2]. The cadmium (Cd) is one of the most toxic heavy metals with strong toxic to biology, especially to vegetable, and the vegetable is the indispensable part of human diet [3]. In agricultural production, reasonable intercropping can be used to improve the effective utilization of soil nutrients, water and light resources [4], and the appropriate planting density has been considered as one of the key factors to improve the yield and quality of vegetables [5]. When the roots of two species contacting, the root exudates may affect the soil heavy metal ions to increase or decrease the absorption of heavy metal ions by plant [6]. The zinc hyperaccumulator plant *Sedum alfredii* intercropping with maize, the heavy metal accumulation in grain of maize reduces significantly compared with monoculture [7]. The other studies shows that Cd hyperaccumulator plant *Thlaspi caerulescens* intercropping with *Brassica pekinensis* does not increase the Cd content in *B. pekinensis* [8]. *Galinsoga parviflora* is a Cd hyperaccumulator [9], and radish is an important common vegetable. To decrease the Cd content in radish, the effects of intercropping different density of Cd-hyperaccumulator *G. parviflora* on Cd accumulation of radish were investigated in this study. The aim of the study was to screen intercropping density of *G. parviflora* which could decrease Cd content in radish, and provide a reference for other vegetables.

Materials and Method

Materials. The inceptisol soil samples were collected from Ya'an campus farm of 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]. *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 May 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 $CdCl_2 \cdot 2.5H_2O$ 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 radish 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 three 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 radish 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 Radish. With the density increasing of *G. parviflora*, the root, tuberous root, leaf, edible part and whole plant biomasses of radish decreased (Table 1). The biomass of radish was ranked as: radish (monoculture) > radish (intercropping with 1 *G. parviflora*) > radish (intercropping with 2 *G. parviflora*) > radish (intercropping with 3 *G. parviflora*) > radish (intercropping with 4 *G. parviflora*) > radish (intercropping with 5 *G. parviflora*). When intercropping with 1, 2, 3, 4 and 5 *G. parviflora* seedlings, the root biomass of radish decreased by 4.55% ($p > 0.05$), 13.46% ($p > 0.05$), 27.27% ($p < 0.05$), 50.00% ($p < 0.05$) and 72.73% ($p < 0.05$) respectively compared with monoculture, and the edible part biomass of radish decreased by 3.76% ($p > 0.05$), 17.62% ($p > 0.05$), 46.12% ($p < 0.05$), 50.51% ($p < 0.05$) and 77.37% ($p < 0.05$) respectively compared with monoculture, and the whole plant biomass of radish decreased by 3.77% ($p > 0.05$), 17.55% ($p > 0.05$), 45.80% ($p < 0.05$), 50.50% ($p < 0.05$) and 77.29% ($p < 0.05$) respectively compared with monoculture. Therefore, intercropping with *G. parviflora* inhibited radish growth, which was not suitable for enhancing the yield of radish.

Table 1 Effects of intercropping density with *G. parviflora* on biomass of radish

Treatments	Root (g/plant)	Tuberous root (g/plant)	Leaf (g/plant)	Edible part (g/plant)	Whole plant (g/plant)
Radish (monoculture)	0.22±0.02a	5.43±0.13a	7.34±0.22a	12.77±0.35a	12.99±0.37a
Radish (1 *G. parviflora*)	0.21±0.03a	5.39±0.03a	6.90±0.14ab	12.29±0.17a	12.50±0.19a
Radish (2 *G. parviflora*)	0.19±0.02ab	4.45±0.07b	6.07±0.64b	10.52±0.71b	10.71±0.73b
Radish (3 *G. parviflora*)	0.16±0.02b	1.94±0.09c	4.94±0.26c	6.88±0.34c	7.04±0.36c
Radish (4 *G. parviflora*)	0.11±0.03c	1.48±0.06d	4.84±0.10c	6.32±0.16c	6.43±0.17c
Radish (5 *G. parviflora*)	0.06±0.01d	0.76±0.03e	2.13±0.52d	2.89±0.55d	2.95±0.56d

Cd Content in Radish. After intercropping with *G. parviflora*, the Cd contents in root, tuberous root, leaf, edible part and whole plant of radish increased when the density of *G. parviflora* was not more than 3, and decreased when the density of *G. parviflora* was higher than 3 (Table 2), which was consistent with other studies [10]. The Cd contents in root, tuberous root, leaf, edible part and whole plant of radish was ranked as: radish (intercropping with 3 *G. parviflora*) > radish (intercropping with 4 *G. parviflora*) > radish (intercropping with 5 *G. parviflora*) > radish (intercropping with 2 *G. parviflora*) > radish (intercropping with 1 *G. parviflora*) > radish (monoculture). When intercropping with 1, 2, 3, 4 and 5 *G. parviflora* seedlings, the Cd content in root of radish increased by 149.61% (*p*

< 0.05), 331.25% ($p < 0.05$), 675.78% ($p < 0.05$), 512.50% ($p < 0.05$) and 334.38% ($p < 0.05$) respectively compared with monoculture, and the Cd content in edible part of radish increased by 68.96% ($p < 0.05$), 82.71% ($p < 0.05$), 350.42% ($p < 0.05$), 202.08% ($p < 0.05$) and 176.46% ($p < 0.05$) respectively compared with monoculture, and the Cd content in whole plant biomass of radish increased by 69.75% ($p < 0.05$), 85.08% ($p < 0.05$), 353.36% ($p < 0.05$), 205.04% ($p < 0.05$) and 177.94% ($p < 0.05$) respectively compared with monoculture. So, intercropping with *G. parviflora* could increase Cd content in radish, Therefore, in the Cd contamination farmland, intercropping with *G. parviflora* to reduce Cd content in radish should be carefully considered.

Table 2 Effects of intercropping density with *G. parviflora* on Cd accumulation of radish

Treatments	Root (mg/kg)	Tuberous root (mg/kg)	Leaf (mg/kg)	Edible part (mg/kg)	Whole plant (mg/kg)
Radish (monoculture)	2.56±0.25e	2.88±0.11e	6.22±0.31d	4.80±0.22d	4.76±0.23d
Radish (1 *G. parviflora*)	6.39±0.55d	3.86±0.34d	11.43±0.96c	8.11±0.66c	8.08±0.66c
Radish (2 *G. parviflora*)	11.04±1.30c	4.66±0.23c	11.79±1.26c	8.77±0.67c	8.81±0.68c
Radish (3 *G. parviflora*)	19.86±1.84a	8.72±0.31a	26.69±2.39a	21.62±1.78a	21.58±1.78a
Radish (4 *G. parviflora*)	15.68±0.96b	5.85±0.20b	17.14±0.79b	14.50±0.68b	14.52±0.69b
Radish (5 *G. parviflora*)	11.12±0.33c	4.98±0.12c	16.23±1.30b	13.27±0.51b	13.23±0.51b

Cd Accumulation of *G. parviflora*. After intercropping with radish, 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 3). Compared with 1 *G. parviflora*, the shoot biomasses of 2, 3 and 4 *G. parviflora* increased by 12.50% ($p > 0.05$), 29.64% ($p < 0.05$) and 8.93% ($p > 0.05$) respectively, and 5 *G. parviflora* decreased by 2.14% ($p > 0.05$). The biomass of *G. parviflora* was ranked as: 3 *G. parviflora* > 2 *G. parviflora* > 4 *G. parviflora* > 1 *G. parviflora* > 5 *G. parviflora*. The Cd contents in roots and shoots of *G. parviflora* increased with the density increase of *G. Parviflora* (Table 3). The Cd content in *G. parviflora* was ranked as: 5 *G. parviflora* > 4 *G. parviflora* > 3 *G. parviflora* > 2 *G. parviflora* > 1 *G. parviflora*. The number of *G. parviflora* greater in unit area, the more Cd was absorbed, which is consistent with other studies [11-12]. Compared with 1 *G. parviflora*, the Cd content in shoots of 2, 3, 4 and 5 *G. parviflora* increased by 5.49% ($p > 0.05$), 13.31% ($p > 0.05$), 28.72% ($p < 0.05$) and 37.22% ($p < 0.05$) respectively. With the increase of density, the Cd exaction by roots of *G. parviflora* increased when the density was not more than 4, and decreased when the density was higher than 4 (Table 3). The Cd exaction by shoots of *G. parviflora* increased when the density was not more than 3, and decreased when the density was higher than 3. The Cd exaction by roots of *G. parviflora* was ranked as: 4 *G. parviflora* > 3 *G. parviflora* > 5 *G. parviflora* > 2 *G. parviflora* > 1 *G. parviflora*, and the Cd exaction by shoots of *G. parviflora* was 3 *G. parviflora* > 4 *G. parviflora* > 5 *G. parviflora* > 2 *G. parviflora* > 1 *G. parviflora*. Compared with 1 *G. parviflora*, the Cd extraction by shoots of 2, 3, 4 and 5 *G. parviflora* increased by 18.69% ($p < 0.05$), 46.91% ($p < 0.05$), 40.21% ($p < 0.05$) and 34.29% ($p < 0.05$) respectively.

Table 3 Effects of intercropping density with *radish* on Cd accumulation of *G. parviflora*

Treatments	Biomass (g/plant)		Cd content (mg/kg)		Cd extraction (μg/plant)	
	Roots	Shoots	Roots	Shoots	Roots	Shoots
1 *G. parviflora*	0.93 ±0.01a	2.80 ±0.10b	16.44±0.62c	20.58±0.82c	15.34±0.42d	57.62±0.26d
2 *G. parviflora*	0.95 ±0.02a	3.15 ±0.14ab	16.81±0.44bc	21.71±1.00bc	15.97±0.06d	68.39±0.09c
3 *G. parviflora*	0.98±0.01a	3.63 ±0.17a	18.65±0.64b	23.32±1.08abc	18.28±0.36b	84.65±0.06a
4 *G. parviflora*	0.94±0.01a	3.05 ±0.35b	20.66±0.93a	26.49±3.44ab	19.46±0.64a	80.79±1.12b
5 *G. parviflora*	0.80 ±0.04b	2.74 ±0.09b	21.59±0.99a	28.24±1.75a	17.27±0.03c	77.38±2.41b

Conclusions

Intercropping different density with *Galinsoga parviflora* decreased the growth of radish. After intercropping with *G. parviflora*, the Cd content in radish increased when the density of *G. parviflora* was not more than 3, and decreased when the density of *G. parviflora* was higher than 3. The Cd content in radish was ranked as: radish (intercropping with 3 *G. parviflora*) > radish (intercropping with 4 *G. parviflora*) > radish (intercropping with 5 *G. parviflora*) > radish (intercropping with 2 *G. parviflora*) > radish (intercropping with 1 *G. parviflora*) > radish (monoculture). When the density was not more than 3, intercropping with radish increased biomass of *G. parviflora*, and decreased when the density was higher than 3. Intercropping with radish increased Cd content in *G. parviflora*. With the increase of density, the Cd exaction by roots of *G. parviflora* increased when the density was not more than 4, and decreased when the density was higher than 4. Therefore, in the Cd-contaminated soil, intercropping with *G. parviflora* was not suitable for radish production.

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