Effects of Intercropping with Floricultural Accumulator Plants on Nutrient Uptake of Grape Seedlings under Cadmium Stress

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Abstract: A pot experiment was carried out to study the effects of intercropping with four floricultural accumulator plants (*Helianthus annuus*, *Cosmos sulphureus*, *Cosmos bipinnata*, *Impatiens balsamina*) on nutrient uptake of grape seedlings under cadmium (Cd) stress. The results showed that intercropping with *C. sulphureus* and *I. balsamina* reduced the nutrient absorption of grape seedlings under Cd stress. Intercropping with *H. annuus* significantly reduced the K content of various organs of grape seedlings compare to monoculture. Only intercropping with *C. bipinnata* significantly increased the N content in leaves, P contents in roots, leaves and shoots, and K content in roots of grape seedlings. Therefore, intercropping with *C. bipinnata* could increase the nutrient absorption of grape seedlings under Cd stress.

Introduction

With the development of mining, smelting, thermal power generation and industrialization, soil heavy metal pollution has become a worldwide problem [1]. Cadmium (Cd) is one of the most toxic heavy metal which will endanger the growth and development of plants and ultimately affect human health [2]. Grape is one of the longest cultivated fruit tree in the world, which is an important branch of China's agricultural industry, with high nutritional and economic value [3]. However, it has been found that some vineyard soils are polluted by heavy metals, which is not conducive to the growth and development of grape [4].

It has been found that intercropping can improve the soil environment and make full use of resources [5-6]. In addition, intercropping Cd accumulator plants can effectively reduce Cd stress on fruit tree and increase the absorption of nutrient in Cd-contaminated soil [7]. Floricultural plants are rich in resources, will not enter the food chain, intercropping with floricultural heavy metal-accumulator plants in the orchard can not only remedy the soil environment, but also beautify the environment [8]. *Helianthus annuus* [9], *Cosmos sulphureus* [10], *Cosmos bipinnata* [11] and *Impatiens balsamina* [12] are floricultural Cd-accumulator plants, which were used to intercrop with grape in Cd-contaminated soil in this study, and the effects of intercropping with four floricultural accumulator plants on nutrient uptake of grape seedlings were studied. The aim of this study was to screen out the best floricultural accumulator plants which could promote the nutrient absorption of grape.

Materials and Methods

Materials collection. The seeds of floricultural plants (*H. annuus*, *C. sulphureus*, *C. bipinnata*, *I. balsamina*) were collected from the farmland of Chengdu Campus of Sichuan Agricultural University and were put into the tray to germinate in April, 2016. The cultivar of grape is Kyoho with cutting seedlings. The fluvo-aquic soil samples were collected from the farmland at Chengdu Campus of Sichuan Agricultural University in April, 2016.

Experimental Design. The experiment was conducted in Chengdu Campus of Sichuan Agricultural University from April to July 2016. In April 2016, the soil was air-dried and passed through a 6.72-mm sieve. 3 kg air-dried soil was weighed into each plastic pot (21 cm high, 20 cm in diameter), soaking uniformly by 5 mg/kg Cd (in the form of $CdCl_2 \cdot 2.5H_2O$) solution for 4 weeks. All pots were watered each day to keep the soil moisture about 80%. In May 2016, three uniform-sized cutting seedlings (the shoots were about 15 cm) of Kyoho grape were transplanted into pot for monoculture. One uniform-sized seedling (two pairs leaves expanded) of each floricultural plant and two grape seedlings were transplanted into each pot for intercropping. The five treatments in experiment were 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 per treatment and the pots placed completely random. The distance between pots was 15 cm, and the pot position exchanged aperiodically to weaken the impact of the marginal effects. The soil moisture content was maintained at 80% of field capacity until the plants were harvested. After 60 days, grape seedlings were dug up and divided into three parts of root, stem, leaf, then washed with tap water firstly, followed by deionized water. After that, the organs of all plants were dried at 80 °C until constant weight, weighed, ground to < 0.149 mm, and sealed into plastic bags for the determination of total nitrogen (N), total phosphorus (P) and total potassium (K) contents [13]. The soil sample was collected, air-dried and ground to < 1.0 mm for analysis of alkali soluble N, available P and available K concentrations [13].

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.

Results and Discussion

Total nitrogen content in grape seedlings. For the roots and stems of grape seedlings, intercropping significantly reduced its N content compared to monoculture in the Cd soil (Table 1). The N content of leaves in grape seedlings was ranked in the following order: intercropping with *C. bipinnata* > in tercropping with *H. annuus* > monoculture > intercropping with *C. sulphureus* > intercropping with *I. balsamina* (Table 1). Compared with monoculture, intercropping with *H. annuus* significantly increased the N content of grape seedlings shoots ($p < 0.05$), intercropping with *C. sulphureus* and *I. balsamina* significantly reduced the N content of grape seedlings shoots, and decreased by 19.10% ($p < 0.05$) and 18.41% ($p < 0.05$) compared to monoculture, respectively.

Table 1 Total nitrogen contents in grape seedlings

Treatments	Roots (mg/g)	Stems (mg/g)	Leaves (mg/g)	Shoots (mg/g)
Monoculture	10.86±0.87a	4.55±0.32a	15.26±0.73b	11.73±0.63b
Intercropping with *H. annuus*	8.07±0.42c	3.73±0.36b	15.38±0.97ab	12.24±0.46a
Intercropping with *C. sulphureus*	7.77±0.69c	3.33±0.48b	12.29±0.89c	9.49±0.78c
Intercropping with *C. bipinnata*	9.30±0.53b	3.39±0.56b	15.90±1.66a	11.61±0.57b
Intercropping with *I. balsamina*	8.23±0.41c	3.64±0.29b	12.03±0.82c	9.57±0.46c

Values are means ± standard errors. Means with the same letter within each column are not significantly different at $p < 0.05$.

Total phosphor contents in grape seedlings. For the leaves and shoots of grape seedlings, intercropping with *C. bipinnata* significantly increased their P content compared to monoculture in the Cd soil, and the other treatments significantly reduced the P content of their leaves and shoots (Table 2). The P content of stems in grape seedlings was ranked in the following order: intercropping with *H. annuus* > monoculture > intercropping with *I. balsamina* > intercropping with *C. bipinnata* > intercropping with *C. sulphureus* (Table 2). Intercropping with *C. bipinnata* significantly increased the P content of grape seedlings roots compared to monoculture ($p < 0.05$), intercropping with *H. annuus*, *C. sulphureus* and *I. balsamina* significantly reduced the P content of grape seedlings roots, and decreased by 20.41% ($p < 0.05$), 22.63% ($p < 0.05$) and 12.92% ($p < 0.05$) compared to monoculture, respectively.

Kalium contents in grape seedlings. Compared with the monoculture, intercropping with *I. balsamina* had little effects on the K content in stems of grape seedlings, and the other treatments significantly reduced the K contents in stems (Table 3). Intercropping with *C. bipinnata* significantly increased the P content of roots in grape seedlings compared to monoculture ($p < 0.05$), intercropping with *H. annuus*, *C. sulphureus* and *I. balsamina* significantly reduced the K contents in its roots, and decreased by 8.24% ($p < 0.05$), 25.66% ($p < 0.05$), 6.33% ($p < 0.05$) compared to monoculture, respectively. The K content of leaves and shoots in grape seedlings both were ranked in the following order: monoculture > intercropping with *I. balsamina* > intercropping with *H. annuus* > intercropping with *C. bipinnata* > intercropping with *C. sulphureus* (Table 3).

Table 2 Total phosphor contents in grape seedlings

Treatments	Roots (mg/g)	Stems (mg/g)	Leaves (mg/g)	Shoots (mg/g)
Monoculture	1.308±0.07b	0.582±0.03b	0.762±0.02b	0.703±0.11b
Intercropping with *H. annuus*	1.041±0.05d	0.634±0.05a	0.719±0.07c	0.696±0.05c
Intercropping with *C. sulphureus*	1.012±0.04e	0.500±0.07d	0.652±0.05d	0.605±0.07e
Intercropping with *C. bipinnata*	1.340±0.03a	0.560±0.04c	0.832±0.04a	0.739±0.06a
Intercropping with *I. balsamina*	1.139±0.05c	0.568±0.06bc	0.640±0.05d	0.619±0.02d

Values are means ± standard errors. Means with the same letter within each column are not significantly different at $p < 0.05$.

Table 3 Kalium contents in grape seedlings

Treatments	Roots (mg/g)	Stems (mg/g)	Leaves (mg/g)	Shoots (mg/g)
Monoculture	14.69±0.54b	8.22±0.71a	13.13±0.56a	11.51±0.55a
Intercropping with *H. annuus*	13.48±0.47d	8.00±0.42b	11.10±0.71c	10.26±0.41c
Intercropping with *C. sulphureus*	10.92±0.51e	6.79±0.59d	7.87±0.43e	7.53±0.68e
Intercropping with *C. bipinnata*	19.29±0.66a	7.50±0.63c	10.51±0.89d	9.48±0.52d
Intercropping with *I. balsamina*	13.76±0.30c	8.30±0.65a	11.87±0.68b	10.83±0.57b

Values are means ± standard errors. Means with the same letter within each column are not significantly different at $p < 0.05$.

Available Nitrogen, Phosphor, Kalium content in soil. Compared with monoculture, intercropping had little effect on N content in the soil (Table 4). Intercropping with *H. annuus*, *C. sulphureus*, *C. bipinnata* and *I. balsamina* significantly reduced the K content in soil, and decreased by 38.05% ($p < 0.05$), 21.98% ($p < 0.05$), 47.99% ($p < 0.05$), 19.96% ($p < 0.05$) compared to monoculture, respectively (Table 4). The P content in soil was ranked in the following order: intercropping with *I. balsamina* > monoculture > intercropping with *C. bipinnata* > intercropping with *H. annuus* > intercropping with *C. sulphureus* (Table 4).

Table 4 Available nitrogen, phosphor, kalium content in soil

Treatments	Alkali soluble N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
Monoculture	118.90±4.25a	25.85±1.35b	124.93±6.33a
Intercropping with *H. annuus*	113.41±3.17a	22.62±1.42c	77.39±2.12c
Intercropping with *C. sulphureus*	118.96±5.44a	20.61±1.27d	97.47±4.95b
Intercropping with *C. bipinnata*	109.17±6.26a	24.74±2.15b	64.98±2.64c
Intercropping with *I. balsamina*	111.98±4.48a	27.80±1.65a	100.00±3.75b

Values are means ± standard errors. Means with the same letter within each column are not significantly different at $p < 0.05$.

Conclusions

Intercropping with *Helianthus annuus*, *Cosmos sulphureus*, *Cosmos bipinnata* and *Impatiens balsamina* affected the nutrient uptake of grape seedlings under Cd stress. Compared to monoculture, intercropping with *C. sulphureus* significantly reduced the N, P, K content of various organs of grape seedlings. Intercropping with *I. balsamina* had little effects on the P, K content in stems of grape seedlings, which significantly reduced the N, P, K content in rest organs of grape seedlings compared to monoculture. Intercropping with *H. annuus* significantly increased the N content in shoots and the P content in stems of grape seedlings, but significantly reduced the K content in various organs of grape seedlings. Intercropping with *C. bipinnata* significantly increased the N content in leaves, P content in roots, leaves and shoots, and K content in roots of grape seedlings. These results indicate that intercropping with *C. bipinnata* could increase the nutrient absorption of grape seedlings under Cd stress.

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