Effects of *Cyphomandra betacea* Seedlings Intercropping with F1 Generations of *Solanum photeinocarpum* on Soil Enzyme Activity under Cadmium Stress

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Abstract: Effects of *Cyphomandra betacea* seedlings intercropping with F_1 generations of *Solanum photeinocarpum* on soil enzyme activity under cadmium (Cd) stress were studied. The activities of soil catalase, soil polyphenol oxidase, soil sucrase, and soil urease were measured. The results showed that under Cd stress, *C. betacea* seedlings intercropping with F_1 generation of *S. photeinocarpum* increased soil polyphenol oxidase and decreased soil catalase activities. *C. betacea* seedlings intercropping *S. photeinocarpum* of mine ecotype and two F_1 generations of *S. photeinocarpum* enhanced soil sucrase activity. *C. betacea* seedlings intercropping two ecotypes F_1 generations of *S. photeinocarpum* enhanced soil urease activity.

Introduction

Cyphomandra betacea belongs to Solanaceae, is a perennial evergreen fruit tree [1], also known as woody tomato, egg fruit, and sour eggplant. The fruit juicy sweet and sour of *C. betacea* can be used for fresh fruit, storage, transportation, is a natural green food, considerable economic benefits, great potential for development [2]. However, the frequent heavy metal pollution in recent years has threatened the growth of fruit trees and the safety of fruits in orchards, which is a major problem to be solved urgently.

At present, there are many methods for the remediation of soil heavy metal pollution, of which phytoremediation is a common method with the advantages of low cost and wide application range [3]. In agriculture, intercropping can improve the crop's efficient use of light, temperature, water, gas and fertilizer to reduce the incidence of pests and diseases and improve the yield and quality of crops [4].In addition, it can improve the soil environment , improve soil enzyme activity and crop nutrient absorption and utilization of soil [5]. When the two plant roots close to each other or contact, can produce "rhizosphere dialogue" phenomenon, this phenomenon can promote or inhibit plant growth [6]. Soil enzyme is a biocatalyst, which is sensitive biological index reflecting soil fertility. It can directly reflect the intensity and direction of soil biochemical processes. Under the condition of heavy metal pollution, heavy metal can occupy the active center of soil enzyme or is related to groups combine into complexes, affecting the enzyme activity in the soil, thereby reducing soil enzyme activity [7-8]. Studies have shown that soil enzyme activity and heavy metal concentrations showed a significant correlation, and its activity as an indicator of ecological effects of heavy metal pollution [9]. The effects of different plants (mixed) on the absorption of heavy metals are mainly concentrated in the rhizosphere. Plants can secrete organic acids by letter feedback and organic acids can form complexes with heavy metals [10], thus reducing the bioavailability of heavy metals, reducing the plant's absorption of heavy metals [11], which is also conducive to the improvement of soil enzyme activity.

Soil enzyme is a biocatalyst, which is a sensitive biological index reflecting soil fertility. It can directly reflect the intensity and direction of soil biochemical processes. However, the accumulation and distribution of heavy metal ions in the soil can easily affect the enzyme activity in the soil [3], the relevant research shows that heavy metals on soil enzyme activity has a strong inhibitory effect [4-6].

Hybrids affect plant uptake of heavy metals mainly by altering the physical and chemical properties of soil enzymes such as soil enzyme activity in the rhizosphere [7-8].

In view of this, the results showed that under the conditions of cadmium (Cd) treatment, the growth status of *Solanum photeinocarpum* parents and *S. photeinocarpum* positive and negative hybridization F_1 generation were observed. To study the effects of two ecotypes of *S. photeinocarpum* and its positive and negative hybridization F_1 generation on the soil enzyme activities in order to screen *S. photeinocarpum* hybridization F_1 generation which can effectively repair Cd pollution in orchard soil and significantly reduce the Cd accumulation in tree and *C. betacea*, for orchard soil Cd pollution repair provide reference.

Materials and Methods

Materials. The seeds of *S. photeinocarpum* of mine ecotype were collected from a *S. photeinocarpum* plant at the lead-zinc mine of the Tangjiashan, Hanyuan County, Sichuan, China in October 2014. The seeds of *S. photeinocarpum* of farmland ecotype were collected from a *S. photeinocarpum* plant at the Ya'an campus farm of the Sichuan Agricultural University, China in November 2014.

Intercropping. In March 2015, the collected seeds were directly sown in a plastic basin of 21 cm × 20 cm (diameter × height). The soil for planting *S. photeinocarpum* of farmland ecotype was taken from the farm of Ya'an Campus of Sichuan Agricultural University and the soil for planting *S. photeinocarpum* of mine ecotype was taken from the Tangjiashan lead-zinc mine in Hanyuan County, Sichuan Province. When seedings were mature into the bud, we started hybridization. When the fruit reached physiological maturity, harvested the fruit for colleting the seeds.

Experimental Design. The soil samples were air-dried and passed through a 6.72 mm mesh in July 2015, and then 3.0 kg of soil was weighed into a 21 cm × 20 cm (diameter × height) plastic basin. Cd was added to make a final soil Cd concentration of 10 $mg \cdot kg^{-1}$ with a saturated heavy metal solution in the form of $CdCl_2 \cdot 2.5H_2O$. Kept the soil moist for 30 days and mixed with soil from time to time to mix the soil well. In July 2015, *C. betacea* were bred in a climate chamber. In August 2015, the seeds of *S. photeinocarpum* parental generation and *S. photeinocarpum* positive and negative hybridization F1 generations of (about 3 cm tall, 2 euphyllas expanded) and *C. betacea* seedlings (about 10 cm tall, 3 euphyllas expanded) respectively were planted in pots. *S. photeinocarpum* planted 1 per pot. *C. betacea* seedlings planted 3 per pot for monoculture, and 2 per pot for intercropping. There were five treatments: CK (*C. betacea* monoculture), T1 (*C. betacea* intercropping *S. photeinocarpum* of farmland ecotype), T2 (*C. betacea* intercropping *S. photeinocarpum* of mine ecotype), T3 (*C. betacea* intercropping *S. photeinocarpum* positive hybridization F_1 generation), and T4 (*C. betacea* intercropping *S. photeinocarpum* positive hybridization F_1 generation) Each treatment was repeated six times with a 15-cm spacing between pots, and completely randomized. The soil moisture content was maintained at 80% of field capacity until the plants were harvested.

Determination Method. Soil urease activity was measured by indophenol blue colorimetry [12], soil sucrase activity was measured by 3, 5-dinitrosalicylic acid colorimetry [12], and soil catalase activity was determined by potassium permanganate titration Method [12], soil polyphenol oxidase activity was measured by colorimetric method [13].

Results and Discussion

Soil Catalase Activity. Under Cd stress, *C. betacea* intercropping *S. photeinocarpum*, soil catalase was significantly different from CK ($P < 0.05$), but there was no significant difference among the intercropping treatments ($P < 0.05$). T1, T2, T3, and T4 compared with *C. betacea* seedlings decreased by 12.63%, 13.53%, 19.50% and 15.78% (Fig. 1).

Soil Polyphenol Oxidase Activity. Under Cd stress, *C. betacea* intercropping *S. photeinocarpum*, soil polyphenol oxidase improved significantly ($P < 0.05$). T3 and T4 were significantly higher than

T1 and T2. The results showed that the soil polyphenol oxidase value was the highest (0.241 ml·g^{-1}) when T3 was processed (Fig. 2).

Soil Sucrase Activity. As can be seen from Fig. 3, soil sucrase was significantly increased except T1 ($P < 0.05$). T3 soil sucrase reached the highest level, 49.62% ($P < 0.05$) higher than *C. betacea*.

Soil Urease Activity. As can be seen from Fig. 4, the soil urease activity of T3 and T4 increased significantly by 27.45% and 17.69% ($P < 0.05$). Nevertheless, T1 and T2 didn't increase soil urease activity ($P < 0.05$).

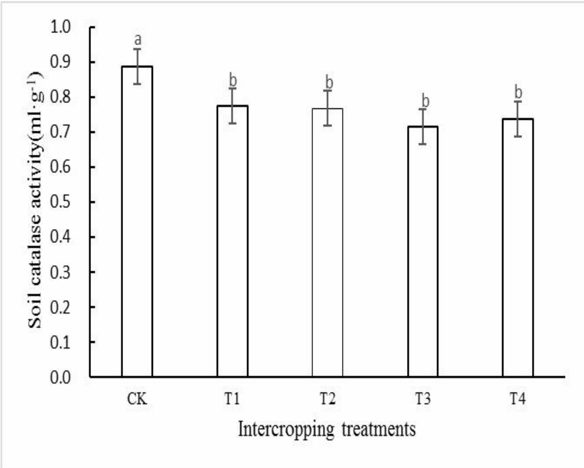

Fig. 1 Soil catalase activity

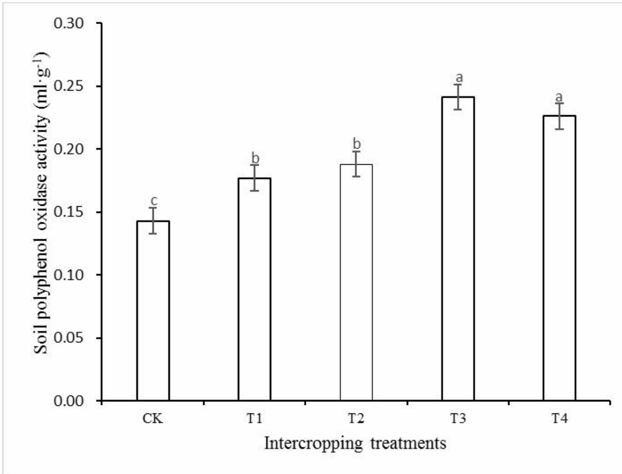

Fig. 2 Soil polyphenol oxidase activity

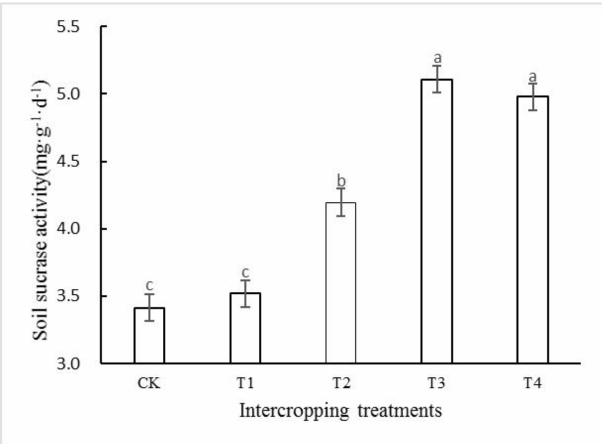

Fig. 3 Soil sucrase activity

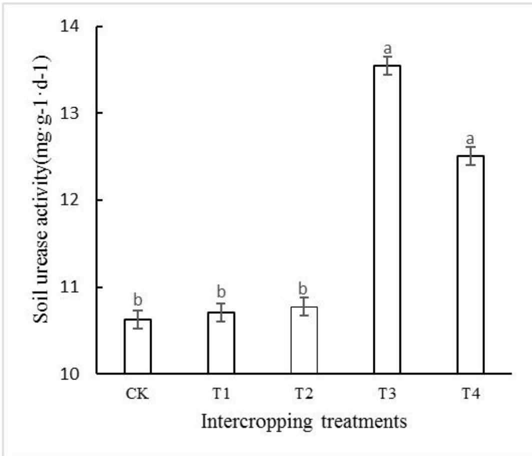

Fig. 4 Soil urease activity

Conclusions

C. betacea intercropping two ecotypes of *S. photeinocarpum* and their hybridization F1 generation had different effects on improving soil enzyme activities. Among them, the improvement of soil enzyme activity after *C. betacea* intercropped two ecotypes of *S. photeinocarpum* hybridization F1 generation was better than that of *C. betacea* intercropping two ecotypes of *S. photeinocarpum*, which indicated that the root exudates of *C. betacea* intercropping two ecotypes of *S. photeinocarpum* had limitations on the improvement of Cd-contaminated soil environment, while two ecotypes of *S. photeinocarpum* hybridization F_1 generation can break this limitation and further improve the soil environment. Therefore, two ecotypes of *S. photeinocarpum* hybridization F_1 generation were most beneficial to the ecological environment of Cd-contaminated soils improvement in this experiment.

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