Effects of *Lycopersicon esculentum* and *Solanum melongena* intercropping with *Solanum nigrum* on soil enzyme activity under cadmium stress

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Abstract. A pot experiment was conducted to study the effects of *Lycopersicon esculentum* and *Solanum melongena* intercropping with *Solanum nigrum* on soil enzyme activity under cadmium (Cd) stress. The result showed that after *S. nigrum* intercropping with *L. esculentum* and *S. melongena*, respectively, only the soil sucrase activity was decreased, soil urease activity, phosphatase activity and catalase activity were increased compared with the three monocultures. Therefore, intercropping with *S. nigrum* increases soil enzyme activity, and intercropping with *S. melongena* is more effective than intercropping with *L. esculentum* to enhance soil enzyme activity under Cd stress.

1. Introduction

Cadmium (Cd) is a rare dispersing element and one of the more toxic heavy metal elements. It harms the growth and development of plants and enters the human body through the food chain and endangers human health. Excessive intake of cadmium can cause bone pain, kidney damage and even cancer. The sources of cadmium pollution in plants are mainly waste gas, sewage, and sewage [1-3]. As a biocatalyst, soil enzymes are involved in many important biochemical processes in the soil. Soil enzymes are an important part of soil biochemical properties. Its activity reflects the intensity and direction of various biological activities carried out in the soil and is an important indicator for evaluating soil fertility [4-6]. Distribution of heavy metal ions in soil will affect soil enzyme activity and it is feasible to detect soil heavy metal pollution by soil enzyme activity [7-8]. Intercropping can not only improve the balanced absorption of soil nutrients, but also improve the soil environment and increase soil enzyme activity and microbial population [9-10]. *Lycopersicon esculentum* and *Solanum melongena* is an important vegetable consumed by residents in China [11]. Studies have shown that the amount of Cd and Zn contained in the edible and inedible parts of *L. esculentum* and *S. melongena* in the third-grade contaminated soil exceeded the standard [12]. Therefore, in this study, we used Cd hyperaccumulator plants *Solanum nigrum* [13] intercropping with *L. esculentum* and *S. melongena* under Cd stress to study the effects on soil enzyme activity, that could screen out which intercropping treatment significantly increase the soil enzyme activity.
2. Materials and Methods

2.1. Materials collection
The contaminated soil used in the experiment is a fluvo-aquic soil from the Chengdu Campus Farm of Sichuan Agricultural University. The basic properties of the soil were pH 7.09, total nitrogen content 1.50 g/kg, total phosphorus content 0.76 g/kg, total potassium content 18.02 g/kg, alkali nitrogen content 94.82 mg/kg, available phosphorus content 6.30 mg/kg, available potassium content 149.59 mg/kg, total cadmium content 0.02 mg/kg [14]. The seeds of *S. nigrum*, *L. esculentum* and *S. melongena* are self-retained.

2.2. Experimental Design
The experiment was conducted in Chengdu Campus of Sichuan Agricultural University from March to July 2017. In March 2017, 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 10 mg/kg Cd (in the form of CdCl₂·2.5H₂O) solution for 4 weeks [15]. All pots were watered each day to keep the soil moisture about 80%. In April 2017, the seeds of *L. esculentum* and *S. melongena* were gilded for 15 min at 55 °C, soaked for 6 h, and then sown in a 72-well tray in a 28 °C incubator for seedling and planted in pots when two real leaves were used. Five treatments were set up in the experiment: *S. nigrum* for monoculture, *L. esculentum* for monoculture, *S. melongena* for monoculture, *S. nigrum* intercropping with *L. esculentum*, *S. nigrum* intercropping with *S. melongena*. Six uniform seedlings were transplanted into each pot for monoculture and three of them for intercropping, respectively, and each treatment were repeated six times. The distance between pots was 15 cm, and the pot position exchanged aperiodically to weaken the impact of the marginal effects. After 60 days, collected soil separately and soil invertase activity, soil urease activity, soil phosphatase activity and soil catalase activity were measured [16]. The activity of catalase was expressed as the volume of 0.02 mol/L KMnO₄ per gram of soil at room temperature in 30 minutes. Soil urease activity was expressed in grams (mg) of NH₃-N per gram of soil at 37 °C for 24 hours. Soil invertase activity was expressed in the amount of glucose released per gram of soil at 37 °C for 24 hours. Soil phosphatase was expressed in grams of phenol per gram of soil.

2.3. Statistical Analyses
Statistical analyses were conducted using statistical software of SPSS 20.0. Date were analyzed by one-way ANOVA with least significant difference at 5% confidence level.

3. Results and Discussion

3.1. Soil catalase activity of three plants
*S. nigrum* intercropping with *L. esculentum* and *S. melongena*, respectively, decreased the soil invertase activity under Cd stress compared with the three monocultures (Figure 1). When *S. nigrum* intercropped with *S. melongena*, the soil invertase activity was decreased by 17.03% (*p* < 0.05) and 33.70% (*p* < 0.05) than that monoculture of *S. nigrum* and *S. melongena*. When *S. nigrum* intercropped with *L. esculentum*, the soil invertase activity was decreased by 8.51% (*p* < 0.05) and 30.00% (*p* < 0.05) than that monoculture of *S. nigrum* and *L. esculentum*.

3.2. Soil urease activity of three plants
The soil urease activity of *L. esculentum* and *S. melongena* intercropping respectively with *S. nigrum* increased compared with the three monocultures under Cd stress (Figure 2). When *S. nigrum* intercropped with *S. melongena*, the soil urease activity was increased by 24.46% (*p* > 0.05) and 16.64% (*p* > 0.05) than that monoculture of *S. nigrum* and *S. melongena*. When *S. nigrum* intercropped with *L. esculentum*, the soil urease activity was increased by 5.05% (*p* > 0.05) and 16.68% (*p* > 0.05) than that of *S. nigrum* and *L. esculentum* for monoculture, respectively.
3.3. Soil phosphatase activity of three plants

The soil phosphatase activity of L. esculentum and S. melongena intercropping respectively with S. nigrum increased lightly compared with the three monocultures under Cd stress (Figure 3). The soil phosphatase activity was no significant difference between L. esculentum intercropping with S. nigrum and the monoculture of L. esculentum. The treatment of S. melongena is the same. When S. nigrum intercropped with S. melongena and L. esculentum, the soil phosphate activity was increased by 6.20% (p > 0.05) and 8.83% (p < 0.05) than that monoculture of S. nigrum.
3.4. Soil sucrase activity of three plants

Soil catalase activity and soil urease activity have the similar trends. The soil catalase activity of *L. esculentum* and *S. melongena* intercropping respectively with *S. nigrum* increased compared with the three seedlings monoculture under Cd stress (Figure 4). When *S. nigrum* intercropped with *S. melongena*, the soil catalase activity was increased by 6.20% (*p > 0.05*) and 13.46% (*p < 0.05*) than that monoculture of *S. nigrum* and *S. melongena*, respectively. When *S. nigrum* intercropped with *L. esculentum*, the soil catalase activity was increased by 2.52% (*p > 0.05*) and 27.47% (*p < 0.05*) than monoculture of *S. nigrum* and *L. esculentum*, respectively.

4. Conclusions

In this study, when *S. nigrum* intercropped with *L. esculentum* and *S. melongena*, respectively, only the soil sucrase activity was decreased, the soil urease activity, soil phosphatase activity and catalase activity were increased compared with the monoculture of *S. nigrum*, *L. esculentum* and *S. melongena*, respectively. This shows that *S. nigrum* intercropping with *L. esculentum* and *S. melongena*, respectively, improves the microbial environment of cadmium contaminated soil. In conclusion, intercropping treatments had improvement effects on soil enzyme activity.

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