Effect of Intercropping of Solanum nigrum L., Tomato and Eggplant on Phosphorus Uptake under Cadmium Stress

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Abstract: A pot experiment was conducted to study the effect of intercropping S. nigrum, tomato and eggplant on the phosphorus content under cadmium stress. The results showed that the content of phosphorus in roots, stems, leaves and aboveground parts of S. nigrum (intercropping with tomato) was increased by 6.15%, 76.98%, 4.90% and 39.71%, respectively. The phosphorus content in roots, stems, leaves and aboveground parts of tomato (intercropping with S. nigrum) decreased by 10.64%, 26.85%, 7.73% and 19.08%, respectively, after intercropping of S. nigrum and tomato. The intercropping of S. nigrum and eggplant increased the content of phosphorus in roots, stems, leaves and aboveground parts, and the content of phosphorus in roots, stems, leaves and aboveground parts of S. nigrum (intercropping with eggplant) increased by 9.57%, 130.47%, 51.47% and 91.87%, respectively. The phosphorus content in roots, stems, leaves and aboveground parts of eggplant (intercropping with S. nigrum) increased by 0.85%, 8.83%, 66.77% and 33.12%, respectively. Therefore, intercropping of S. nigrum and eggplant can increase the phosphorus content of both and increase their absorption of soil nutrients.

1. Introduction
Soil nutrients are important substances for plant growth and play an important role in plant physiological metabolism and growth. In agricultural production, intercropping is often used to increase soil nutrient absorption [1-2]. Under heavy metal pollution conditions, the intercropping of different plant will produce a "rhizosphere dialogue" in the rhizosphere environment. This "internal rhizosphere dialogue" affects the uptake of heavy metals by plants, which in turn affects plant growth [3]. Reasonable intercropping can significantly increase the absorption of soil nutrients in crops under heavy metal pollution conditions. The study showed that the roots and aboveground parts of the rootstock cherry were all differently higher than the cherry monoculture, and the roots and shoot parts of the rootstock cherry of Conyza canadensis (Farmland ecotype) were intercropping. The total potassium content is lower than that of the intercropped C. canadensis (Mining ecotype) by Lin [4]. The result showed that the phosphorus and potassium contents increased significantly after intercropping with cherries and C. canadensis, but the content of phosphorus and potassium did not change or even decreased after cherries intercrop with S. nigrum and D. sanguinalis. Contrary to cherries, the phosphorus and potassium contents of roots and aerial parts of different ecotype of accumulator plants increased after intercropping [5]. Therefore, the cadmium hyperaccumulator plant S. nigrum intercropped with tomato and eggplant, respectively, in this experiment. The absorption of
phosphorus by three plants was studied, which provided certain basis for rational intercropping under cadmium stress.

2. Materials and Methods

2.1. Materials

*S. nigrum* is collected from farmland around Sichuan Agricultural Chengdu Campus, tomato and eggplant was purchased from the surrounding market of Sichuan Agricultural University Chengdu Campus.

2.2. Experimental design

The soil samples were air-dried and passed through a 5-mm mesh, and then 3.0 kg of soil was weighed into each polyethylene pot 21 cm × 20 cm (diameter × height). CdCl₂·2.5H₂O solution was added to the soil to divide the content into 10 mg/kg. The soils were mixed immediately and again after 4 weeks. During this period, soil moisture was kept at 80%. In November 2017, *S. nigrum*, tomato and eggplant seeds were seeded and planted in pots when two true leaves were planted. The treatments are: the monoculture of *S. nigrum*, the monoculture of tomato, the monoculture of eggplant, intercropping with *S. nigrum* and tomato, intercropping with *S. nigrum* and eggplant, four plants were planted per pot in a single plant, and two plants were planted per pot in intercropping plant, and each treatment was repeated three times. After 60 days, the whole plant was harvested. The roots, stems and leaves of *S. nigrum*, tomato and eggplant seedlings were separated and washed with tap water, then rinsed with deionized water for 3 times, then dried at 110°C for 15 min, dried at 75°C to balance weight, and pulverized. After passing through a 0.149 mm sieve, the dried sample was weighed to determine the total phosphorus content of each part.

2.3. Statistical analyses

Statistical analysis was carried out by using SPSS 20.0 statistical software. The data were analyzed by one-way ANOVA, with the least significant difference at the 5% confidence level.

3. Results and Discussion

3.1. Phosphorus content in roots

The phosphorus content in the roots of *S. nigrum* (intercropping with tomato) and *S. nigrum* (intercropping with eggplant) was significantly higher than the monoculture of *S. nigrum*, which increased by 6.15% and 9.57%, respectively (figure 1). Compared with the monoculture of tomato, tomato (intercropping with *S. nigrum*) significantly decreased, declined by 10.64%. While the phosphorus content in the roots of eggplant (intercropping with *S. nigrum*) rose more than the monoculture of eggplant, but the difference was not significant. It indicated that the intercropping with *S. nigrum* and tomato increased the phosphorus content in the roots of *S. nigrum* and reduced the phosphorus content in roots of tomato. The intercropping with *S. nigrum* and eggplant increased the phosphorus content in the roots of both.

3.2. Phosphorus content in stems

By intercropping, the phosphorus content in the stems of *S. nigrum* (intercropping with tomato) and *S. nigrum* (intercropping with eggplant) is significantly higher than the monoculture of *S. nigrum*, *S. nigrum* (intercropping with eggplant) increases the most and it increase of 130.47% (figure 2). Compared with the monoculture of tomato, the phosphorus content in the stems of tomato (intercropping with *S. nigrum*) significantly decreased, decreased by 26.85%. While the phosphorus content in the stems of eggplant (intercropping with *S. nigrum*) increased by 8.83% compare with the monoculture of eggplant. It was indicated that the phosphorus content in the stems of *S. nigrum* and eggplant was increased by intercropping, and the phosphorus content in tomato stems was reduced.
under cadmium stress.

3.3. Phosphorus content in leaves
Compared with the monoculture of *S. nigrum*, *S. nigrum* (intercropping with tomato) increased by 4.90%, *S. nigrum* (intercropping with eggplant) increased by 51.47% (figure 3). Compared with the monoculture of tomato, tomato (intercropping with *S. nigrum*) decreased by 7.73%. Eggplant (intercropping with *S. nigrum*) increased by 66.77% compared with the monoculture of eggplant. It was indicated that the intercropping with *S. nigrum* and eggplant increased the phosphorus content in the leaves of both, and the intercropping with *S. nigrum* and tomato increased the phosphorus content of the leaves of *S. nigrum* and reduced the phosphorus content in leaves of tomato under cadmium stress.

3.4. Phosphorus content in aboveground parts
The intercropping with *S. nigrum* and tomato or eggplant, respectively, the phosphorus content in the aboveground parts of *S. nigrum* (intercropping with tomato) and *S. nigrum* (intercropping with eggplant) are higher than the monoculture of *S. nigrum*, and *S. nigrum* (intercropping with eggplant) reaches its maximum, which increases 91.87% (figure 4). The intercropping with tomato and *S. nigrum*, the phosphorus content in the aboveground parts of tomato (intercropping with *S. nigrum*) decreased by 19.08% compared with the monoculture of tomato. The intercropping with eggplant and *S. nigrum*, the phosphorus content in the aboveground parts was increased by 33.12% compared with the monoculture of eggplant.

Figure 1 Effect of intercropping on phosphorus content in roots under cadmium stress. Mon-Sn means the monoculture of *S. nigrum*; Sn-T means *S. nigrum* (intercropping with tomato); Sn-E means *S. nigrum* (intercropping with eggplant); Mon-T means the monoculture of tomato; T-Sn means tomato (intercropping with *S. nigrum*); Mon-E means the monoculture of eggplant; E-Sn means eggplant (intercropping with *S. nigrum*).

The same as follow.

Figure 2 Effect of intercropping on phosphorus content in stems under cadmium stress
Figure 3 Effect of intercropping on phosphorus content in leaves under cadmium stress

Figure 4 Effect of intercropping on phosphorus content in aerial parts under cadmium stress

4. Conclusions
Under cadmium stress conditions, the intercropping with different plant had different effects on phosphorus content. According to the above indicators, S. nigrum and tomato intercropped, which increased the content of phosphorus in roots, stems, leaves and aboveground parts of S. nigrum (intercropping with tomato), and reduced the content of phosphorus in roots, stems, leaves and aboveground parts of tomato (intercropping with S. nigrum). The intercropping with S. nigrum and eggplant increased the content of phosphorus in both roots, stems, leaves and aboveground parts, and increased the most in S. nigrum (intercropping with eggplant), indicating that plants can be improved by suitable plant by intercropping. It shows that the plant can increase the absorption of soil nutrients by intercropping of suitable plant.

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