Comparative study on the cadmium accumulation of five colour cherry tomato seedlings

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Abstract. In order to study the differences in cadmium (Cd) accumulation and biomass of different colour cherry tomato seedlings under Cd (10 mg/kg) stress, five different colour cherry tomatoes were used as experimental objects in pot experiments. Studies have shown that the biomass of stems, leaves and above-ground parts of yellow and pink cherry tomatoes (yellow and pink) was higher, and the Cd content in the three parts was lower. The biomass of roots, stems, leaves and above-ground parts of purple and green cherry tomatoes (purple and green) was lower, and their Cd content was higher in stems, leaves and above-ground parts. Red cherry tomato (red) had higher biomass of roots, leaves and shoot, and its Cd content in leaves and shoot was also the highest.

1. Introduction
Cherry tomato containing a variety of vitamins and minerals, rich in nutritional value and medicinal value, is selected as one of the preferentially promoted "four fruits" by the United Nations food and agriculture organization [1]. Cadmium (Cd) is a heavy metal with strong mobility and high biological toxicity [2], which is apt to have toxic effects on plants [3] and endanger human’s health [4]. For people, 70% of the heavy metals in the body come from vegetables [5], and the Cd pollution is the most serious [6, 7].

Different vegetable crops have different accumulation of heavy metals, and generally show leafy vegetables > cauliflower vegetables > rhizome vegetables > solanum vegetables > cereal vegetables [8]. Some tomato varieties are of low Cd accumulation [9], and tomatoes have a certain tolerance to Cd poisoning [10]. Tolerance of plants to heavy metals, that is, when the concentration of heavy metals changes the biomass of the above-ground part and root of the plant changes little [11]. Studies have shown that the difference in Cd content in roots, stems and leaves of tomato seedlings under high concentration of Cd (10 µmol/L) pollution is particularly obvious, among which the Cd content in the stems is the lowest [12], but the Cd accumulation of tomato seedlings with different genotypes under Cd stress is different [13]. Therefore, screening cherry tomato materials with low Cd accumulation and high biomass is very important.

2. Materials and methods

2.1 Materials
Yellow (RTY-3-2), purple (purple coffee), pink (pink cherry 14-1), green (Y6-1) and red (red cherry 5-5-1-1) five cherry tomatoes, all of them were self-retaining strains of Sichuan Agricultural University. It is a multi-generation inbred line with homozygous traits.

The test soil was from paddy soil of farmland around Sichuan Agricultural University, and its basic physical and chemical properties are: pH 6.29, organic matter 21.16 g/kg, total nitrogen 1.09 g/kg, total phosphorus 1.2 g/kg, total potassium 22 g/kg, total Cd 0.10 mg/kg, alkaline hydrolyzed nitrogen 68.12 mg/kg, available phosphorus 16.22 mg/kg, available potassium 156.2 mg/kg, and available Cd 0.028 mg/kg [14].

2.2 Experimental design
The concentration of Cd pollution in the tested soil combined with the current actual situation of Cd pollution in farmland in Sichuan area, with reference to "Soil Environmental Quality Standards" (GB15618-1995) and the similar research experiments on various vegetables under Cd stress design, after comprehensive consideration, a concentration of 10 mg/kg Cd was selected for the controlled simulated pollution test [15-16]. In March 2017, the air-dried test soil was sieved through a 5 mm sieve and placed in a 30 cm × 40 cm (diameter × height) bucket, and each bucket contained 18 kg of soil. According to the designed pollution concentration of 10 mg/kg, heavy metal Cd was added to the test soil in the form of pure solution of CdCl$_2$·2.5H$_2$O. After being kept wet and placed for 30 days, all contaminated soil was mixed together thoroughly, and then loaded into plastic basins of 18 cm×26 cm (high × diameter), and each basin was loaded with 6 kg of soil.

In April 2017, tomato seeds with full grains were selected, sterilized in a 10% (m/m) hydrogen peroxide solution for 10 minutes, and then washed with ultrapure water. Spread the sterilized seeds in a petri dish, keep sufficient moisture, put them in a light incubator to promote germination, and then plant them in a tray which is a special substrate for vegetables. When the seedlings grew 3 true leaves and the growth was stable, chose tomatoes of the same size and moved to plastic pots filling the test soil, 6 plants per pot. The test consisted of 5 treatments, yellow, purple, pink, green, and red. Each treatment was repeated 3 times, and watered frequently to keep the soil water holding capacity at 80%. After the tomatoes grown for 30 days, the whole plant was harvested.

2.3 Index determination
Biomass measurement: After washing the soil of the whole plant sample with tap water, rinsed it again with deionized water and wipe it dry. The fresh samples of the plant were divided into roots, stems and leaves, and then the fresh samples were de-enzymed in an oven at 105 °C for 15 min, and then dried at 75 °C to constant weight. Weighed the dry weight with an electronic balance, and calculated the dry weight and root-shoot ratio of the aerial part.

Determination of Cd content: After the roots, stems, and leaves of tomato seedlings dried to constant weight were pulverized and ground, digested them with HNO$_3$-HClO$_4$ (volume ratio of 4:1) and determined with iCAP6300 ICP spectrometer (Thermo Scientific, USA) [14].

2.4 Statistical analyses
Translocation factor: The ratio of the heavy metal content in the shoot of a plant to that in the root. It is an index used to evaluate the ability of plants to transport and enrich heavy metals from root to shoot. It is expressed as S/R. When S/R > 1, it means that the plant mainly concentrates heavy metals in the ground; when S/R <1, heavy metals mainly concentrate in the underground [17].

3. Results
3.1 Comparison of growth of cherry tomatoes of different colors under Cd stress
Under Cd stress, the order of biomass of different parts of cherry tomato was leaf > stem > root (Table 1). Yellow had the highest biomass of stems, leaves and shoot, while purple had the lowest biomass of roots, stems, leaves and shoots. The biomass of roots, stems and leaves of green was lower, and the
shoot biomass of green and purple was significantly lower than the other three cherry tomato materials. The five cherry tomatoes were ranked by the shoot biomass: yellow > red > pink > green > purple, and the same was true of leaf biomass. The results showed that the inhibitory effects of Cd stress on the growth of purple and green were significantly higher than that of other cherry tomato materials, and the inhibitory effect on yellow was the lowest (Table 1).

### Table 1. Biomass of different varieties of cherry tomatoes.

| Treatments | Root (g/plant) | Stem (g/plant) | Leaf (g/plant) | Shoot (g/plant) | Root/shoot ratio |
|------------|----------------|----------------|----------------|----------------|-----------------|
| Yellow     | 1.23±0.16b     | 6.73±0.37a     | 7.64±0.62a     | 14.36±0.88a    | 0.086±0.016b    |
| Purple     | 0.40±0.03e     | 1.37±0.04d     | 3.17±0.27d     | 4.54±0.23d     | 0.089±0.011b    |
| Pink       | 1.06±0.12c     | 5.22±0.44b     | 6.31±0.27b     | 11.53±0.63b    | 0.092±0.009b    |
| Green      | 0.67±0.05d     | 3.16±0.31c     | 4.34±0.10c     | 7.50±0.21c     | 0.089±0.009b    |
| Red        | 1.45±0.04a     | 4.68±0.19b     | 7.12±0.16a     | 11.79±0.06b    | 0.123±0.004a    |

Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 13.0 followed by the least significant difference test (p < 0.05).

#### 3.2 Comparison of Cd content in different color cherry tomatoes under Cd stress

Under Cd stress, the translocation factor of the five cherry tomatoes was less than 1, and the Cd content in the roots was significantly higher than that in the stems, leaves and shoot parts, and the Cd content in the five cherry tomato roots was significantly different (Table 2). The content of Cd in different parts of each material was significantly different, and the order according to the content of Cd was the root > leaf > stem. Red had the lowest Cd content in the root, but the Cd contents in the leaves and shoots were significantly higher than the other four cherry tomato materials. The Cd contents in yellow and pink roots were significantly higher than the other three cherry tomato materials, but the Cd contents in the leaves and shoot were significantly lower than the other three cherry tomato materials. The differences of Cd contents in purple and green roots were significant, but the difference of Cd contents in leaves and stems between the two materials and was not significant (Table 2).

### Table 2. Cd content of different varieties of cherry tomatoes.

| Treatments | Root (g/plant) | Stem (g/plant) | Leaf (g/plant) | Shoot (g/plant) | Translocation factor |
|------------|----------------|----------------|----------------|----------------|---------------------|
| Yellow     | 134.23±10.18a  | 4.94±0.32c     | 23.72±1.08c    | 14.93±0.79c    | 0.111±0.01c         |
| Purple     | 95.30±6.11b    | 11.02±1.03a    | 33.81±3.19b    | 26.91±2.33b    | 0.282±0.02b         |
| Pink       | 125.75±7.93a   | 9.54±0.52b     | 19.11±1.16c    | 14.77±0.59c    | 0.118±0.01c         |
| Green      | 85.11±3.28bc   | 11.52±0.86a    | 35.45±3.06b    | 25.38±1.91b    | 0.299±0.03b         |
| Red        | 80.87±4.24c    | 8.86±0.07b     | 44.21±3.44a    | 30.21±2.48a    | 0.373±0.02a         |

Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 13.0 followed by the least significant difference test (p < 0.05).

#### 4. Conclusions

The Cd content in the five cherry tomato materials was higher under Cd stress. The content of Cd in roots, stems and leaves of each material was significantly different, and the content of Cd in roots was significantly higher than that in vegetative tissues such as stems and leaves. The root, stem, leaf and other vegetative tissues of the five cherry tomato materials were ranked according to the Cd content: root > leaf > stem. For the stem and leaves of the same cherry tomato material, the Cd content was higher in the parts with higher biomass. Cd content in different cherry tomato materials was significantly different. The Cd content in roots of yellow and pink was significantly higher than other cherry tomato materials, but the Cd content in their leaves and shoots was significantly lower than other cherry tomato materials. Red had higher Cd content in roots, stems and leaves. Cd content in roots of purple and green was significantly lower than other cherry tomato materials, but its Cd content in leaves, stems and shoots was higher.
References
[1] Zu, Z., Zhang, B., Huang, W. (2017) Research advances in cherry tomato protected cultivation. Heilongjiang Agricultural Science, 6: 136-140.
[2] Wen, H., Wei, S. (2004) Research progress on Cd-contaminated soil plant extraction technology. Studies on Trace Elements and Health, 5: 52-55.
[3] Liu, S., Fan, Z., Zhang, B., Bi, Y. (2007) Research on Cd Pollution and Its Remediation in China. Shandong Agricultural Sciences, 6: 94-97.
[4] Ding, H., Yang, X. (2007) Research progress on risk assessment of early health effects of environmental Cd hazards. Foreign Medical Sciences (Health), 5: 279-282.
[5] Sun, G., Zhu, Z., Fang, X., Chen, R., Liu, H. (2006) The status and control measures of heavy metal pollution in vegetables in China. Northern Horticulture, 2: 66-67.
[6] Wei, X., He, J., Chen, J., Du, Y., Yang, X. (2002) Investigation and Evaluation of Heavy Metal Pollution in Vegetable Soils in Guangzhou City. Soil and Environment, 3: 252-254.
[7] Feng, M., Wang, P., Wang, J., Jiang, R. (2002) Study on Heavy Metal and Pesticide Pollution in Orchard Soil in the Suburbs of Qingdao. China Fruit Trees, 1: 27-29.
[8] Yang, H., Liang, Q., Zhao, Y., Zhu, C. (2012) Accumulation of heavy metals in seven vegetable crops and the effects of intercropped Japan clover herb on its absorption of heavy metals. Journal of Soil and Water Conservation, 26: 209-214.
[9] Tan, X., Li, Q., He, B., Mei, X., Li, H. (2014) Variety Differences of Tomato Accumulation and Accumulation of Cd. Journal of Jinan University (Natural Science and Medicine Edition), 35: 215-220.
[10] Zhu, F., Fang, W., Yang, Z. (2006) Variety Differences of Cd Absorption and Accumulation Ability of Tomato. Acta Ecological Sinica, 12: 4071-4081.
[11] Zhang, W., Lu, J., Liu, L. (2010) Physiological responses to Cd stress and differences in Cd uptake of tomato seedlings of different genotypes. Journal of Agro-Environment Science, 229: 1065-1071.
[12] Liu L. Effects of Cd on growth and physiological characteristics of different crop seedlings (master thesis). Zhejiang University, 2005.
[13] Zhang W. Study on the difference of Cd absorption of different vegetables (master thesis). Northwest A & F University, 2010
[14] Lin, L., Liao, M., Mei, L. (2014) Two ecotypes of hyperaccumulators and accumulators affect cadmium accumulation in cherry seedlings by intercropping. Environmental Progress and Sustainable Energy, 33: 1251-1257.
[15] Li, H., Wang, J., Lin, L., Liao, M., Lv, X., Tang, Y., Wang, X., Xia, H., Liang, D., Ren, W., Jiang, W. (2019) Effects of mutual grafting on cadmium accumulation characteristics of first post-generations of Bidens pilosa L. and Galinsoga parviflora Cav. Environmental Science and Pollution Research, 26: 33228-33235.
[16] Xia, H., Wang, Y., Liao, M., Lin, L., Zhang, F., Tang, Y., Zhang, H., Wang, J., Liang, D., Deng, Q., Lv, X., Chen, C., Ren, W. (2020) Effects of different rootstocks on cadmium accumulation characteristics of the post-grafting generations of Galinsoga parviflora. International Journal of Phytoremediation, 22: 62-68.
[17] Zhou, J. (2013) Dictionary of soil science. Science Press, Beijing, China.