Comparison of selenium accumulation in three Solanum species

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Abstract. In order to compare the difference of selenium (Se) accumulation in three Solanum species, the Se accumulation characteristics of Solanum nigrum L., Solanum alatum Moench and Solanum nigrum L. var. humile (Bernh.) C. Y. Wu et S. C. Huang were studied by pot experiment at a Se concentration of 10 mg/kg. The results showed that the biomass of all parts of Solanum species was as follows: S. nigrum > S. alatum > S. nigrum var. humile. Interestingly, contrary to the order of Solanum species biomass, the Se content of all parts of Solanum species was as follows: S. nigrum var. humile > S. alatum > S. nigrum. Furthermore, the amount of Se extracted by leaves and shoots was significantly higher than that of other Solanum species, and reached 38.73 and 51.40 μg/plant, respectively. Among the three Solanum species, S. nigrum var. humile has the strongest enrichment ability for soil Se and is an ideal Se-enriched vegetable.

1. Introduction
Selenium (Se) is an essential element that plays an important biological role in animals and humans [1]. Although Enshi, Hubei Province and Ziyang, Shanxi Province, China have abundant Se resources, there is a low-Se district covering about 70% of China area from the northeastern to the southwest, resulting in the Se deficiency of 72% of the population in China [2]. Therefore, appropriately increasing the intake of Se in the human body is conducive to preventing the occurrence of Se-deficient diseases. Se mainly enters the food through the assimilation of plants, but most of the plants have low Se-enriching ability, which not only have limited enrichment ability of Se, but also have protein degradation and leaf atrophy under the higher concentration of Se treatment [3-4]. Therefore, identifying and evaluating more plants with strong Se enrichment ability is important for increasing Se levels in the food chain. Solanum nigrum L. is an annual herb of the genus Solanum whose stems and leaves have quite high nutritional and edible value. Studies have shown that S. nigrum and Solanum alatum Moench can not only grow well but also effectively accumulate Se in soil under the condition of Se concentration of 10 mg/kg [5-6]. Thus, we studied the difference in Se accumulation characteristics of S. nigrum, Solanum alatum Moench and Solanum nigrum L. var. humile (Bernh.) C. Y. Wu et S. C. Huang under the condition of Se concentration of 10 mg/kg, in order to screen out Solanum plant with higher capacity to absorb Se.

2. Materials and methods

2.1. Materials
The test *S. nigrum*, *S. alatum* and *S. nigrum* var. humile seeds were collected in the Sichuan Agricultural University Chengdu Campus (30°71’ N, 103°87’ E) in March 2018. And the seeds were pre-germinated at a climate chamber with 25 °C, relative humidity 70%, 4000 lx, 14 h, in day time, and 20°C, relative humidity 90%, 0 lx, 10 h in night time. Two weeks later, the Solanum seedlings with uniform growth and two real leaves were fully unfolded, which were screened as experimental materials. The tested soil came from the farmland around the Sichuan Agricultural University Chengdu Campus (soil pH was 7.09, total nitrogen content was 1.50 g/kg, total phosphorus content was 0.76 g/kg, total potassium content was 18.02 g/kg, alkali nitrogen content was 94.82 mg/kg, available phosphorus content was 6.30 mg/kg, available potassium content was 149.59 mg/kg and the content of total Se was 0 mg/kg). After the soil was air-dried under shading condition, it was crushed and sieved, and 3.0 kg soil was weighed and placed in a plastic pot of 15 cm high and 18 cm diameter. Then the Na₂SeO₃ solution was irrigated into the soil to maintain the moisture of soil about 60% and the Se content in each pot 10 mg/kg.

2.2. Experimental design

In April 2018, *S. nigrum*, *S. alatum* and *S. nigrum* var. humile seedlings were transplanted into Se-treated soil respectively, four plants were planted in each pot, and each treatment was repeated four times. During the growth of plants, occasional watering to maintain the moisture of soil about 80%, and timely prevention of pests and diseases. The position of the pots and pots was changed occasionally to reduce the marginal effect. After 40 days, all Solanum seedlings were harvested and split into roots, stems and leaves, and then rinsed repeatedly with deionized water. After drying to a constant weight in an oven at 80 °C, weigh the dry samples. And the Se contents of all parts of Solanum seedlings were determined by wet digestion hydride generation atomic fluorescence spectrometry [7].

2.3. Statistical analyses

Statistical analysis was carried out by using SPSS 18.0 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. Biomass of *S. nigrum*, *S. alatum* and *S. nigrum* var. humile

Under the treatment of Se, the biomass of all parts of *S. nigrum*, *S. alatum* and *S. nigrum* var. humile showed significant difference (*p* < 0.05, Table 1). And the rank order of the biomass of the Solanum species was as follows: *S. nigrum* > *S. alatum* > *S. nigrum* var. humile. Compared with *S. nigrum* var. humile, the biomass of roots, stems, leaves and shoots of *S. nigrum* was 33.93% (*p* < 0.05), 34.92% (*p* < 0.05), 24.42% (*p* < 0.05) and 28.63% (*p* < 0.05) higher, respectively.

| Treatments          | Roots (g/plant)   | Stems (g/plant) | Leaves (g/plant) | Shoots (g/plant) |
|---------------------|-------------------|-----------------|------------------|------------------|
| *S. nigrum*         | 0.375±0.010a      | 0.510±0.015a    | 0.703±0.018a     | 1.213±0.033a     |
| *S. alatum*         | 0.340±0.012b      | 0.403±0.014b    | 0.613±0.019b     | 1.016±0.033b     |
| *S. nigrum* var. humile | 0.280±0.009c    | 0.378±0.010c    | 0.565±0.014c     | 0.943±0.024c     |

Values are means ± standard errors of three replicate pots. Different lowercase letters within a column indicate significant differences based on a one-way analysis of variance in SPSS 18.0, followed by the least significant difference test (*p* < 0.05).
3.2. Se content of S. nigrum, S. alatum and S. nigrum var. humile
There were significant differences in Se content in all parts of S. nigrum, S. alatum and S. nigrum var. humile under the treatment of Se ($p < 0.05$, Table 2). And in reverse order to biomass, the rank order of the Se content of the Solanum species was as follows: S. nigrum var. humile > S. alatum > S. nigrum. The Se content of roots, stems, leaves and shoots of S. nigrum var. humile was 33.13% ($p < 0.05$), 62.18% ($p < 0.05$), 51.11% ($p < 0.05$) and 55.82% ($p < 0.05$) higher than S. nigrum, respectively.

Table 2. Se content of S. nigrum, S. alatum and S. nigrum var. humile

| Treatments          | Roots (mg/kg) | Stems (mg/kg) | Leaves (mg/kg) | Shoots (mg/kg) |
|---------------------|---------------|---------------|----------------|----------------|
| S. nigrum           | 125.88±3.61c  | 20.65±0.98c   | 45.39±1.08c    | 34.99±0.23c    |
| S. alatum           | 147.40±4.93b  | 30.48±1.05b   | 59.30±2.03b    | 47.86±1.61b    |
| S. nigrum var. humile | 167.58±5.87a  | 33.49±0.78a   | 68.59±2.39a    | 54.52±1.13a    |

Values are means ± standard errors of three replicate pots. Different lowercase letters within a column indicate significant differences based on a one-way analysis of variance in SPSS 18.0, followed by the least significant difference test ($p < 0.05$).

3.3. The amount of Se extracted by the S. nigrum, S. alatum and S. nigrum var. humile
There was no significant difference in the amount of Se extracted by the roots of S. nigrum, S. alatum and S. nigrum var. humile under Se treatment ($p > 0.05$, Table 3). And there was no significant difference in the amount of Se extracted by the stems of S. alatum and S. nigrum var. humile ($p > 0.05$), but both were significantly higher than S. nigrum ($p < 0.05$). Besides, the amount of Se extracted the leaves and shoots of S. nigrum, S. alatum and S. nigrum var. humile was significant different ($p < 0.05$), and the rank order was as follows: S. nigrum var. humile > S. alatum > S. nigrum. Compared with S. nigrum, the amount of Se extracted by leaves and shoots of S. nigrum var. humile was 21.41% ($p < 0.05$) and 21.14% ($p < 0.05$) higher, respectively.

Table 3. The amount of Se extracted by the S. nigrum, S. alatum and S. nigrum var. humile

| Treatments          | Roots (μg/plant) | Stems (μg/plant) | Leaves (μg/plant) | Shoots (μg/plant) |
|---------------------|------------------|------------------|-------------------|-------------------|
| S. nigrum           | 47.22±0.06a      | 10.53±0.80b      | 31.90±0.07c       | 42.43±0.87c       |
| S. alatum           | 50.11±3.39a      | 12.30±0.85a      | 36.34±2.36b       | 48.64±3.21b       |
| S. nigrum var. humile | 47.03±3.19a     | 12.66±0.63a      | 38.73±0.38a       | 51.40±0.25a       |

Values are means ± standard errors of three replicate pots. Different lowercase letters within a column indicate significant differences based on a one-way analysis of variance in SPSS 18.0, followed by the least significant difference test ($p < 0.05$).

4. Conclusions
The absorption of Se by plants is closely related to the genetic background of the plants themselves. And this study found that S. nigrum, S. alatum and S. nigrum var. humile have significant differences in Se accumulation characteristics under 10 mg/kg Se treatment. The rank order of the biomass of the Solanum species was as follows: S. nigrum > S. alatum > S. nigrum var. humile, and the biomass of all parts of S. nigrum was significantly higher than other Solanum species. Interestingly, contrary to the order of Solanum species biomass, the Se content of all parts of S. nigrum var. humile was significantly higher than other Solanum species, which suggested that there may be a negative correlation between the biomass and Se content of Solanum species. Additionally, there was no significant difference in the amount of Se extracted by the roots of S. nigrum, S. alatum and S. nigrum var. humile. But the amount of Se extracted by the leaves and shoots of S. nigrum var. humile was
significantly higher than other Solanum species, which indicated that *S. nigrum* var. humile has the strongest enrichment ability for soil Se and is an ideal Se-enriched vegetable.

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