Selenium Accumulation Characteristics of *Solanum alatum*

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Abstract: To study the effects of different concentrations of selenium on the selenium accumulation characteristics of *Solanum alatum*, we used the pot experiment to study effects of different selenium concentrations (0, 5, 10, 25, 50, 75, 100 mg/kg) on the biomass and selenium content of *S. alatum*. The results showed that all concentrations of selenium reduced the biomass of *S. alatum*. The biomass of *S. alatum* decreased with the increase of selenium concentration. In addition, with the increase of Se concentration, the Se content of S. *alatum* roots and stems increased. The Se content of *S. alatum* leaves and shoots increased first and then decreased with the increase of Se concentration. The selenium accumulation of each part of *S. alatum* increased first and then decreased with the increase of selenium concentration. Selenium accumulation in *S. alaum* shoots and whole plants were in the ranges of 0.503-13.915 μg/plant and 1.089-18.319 μg/plant respectively under the selenium stress. In all treatments, when the concentration of selenium was 10 mg/kg, the selenium accumulation of each part of *S. alatum* was the highest. Therefore *S. alatum* is most suitable for planting at a selenium concentration of 10 mg/kg.

1. Introduction

Selenium (Se) is one of the essential trace elements in animals and humans and is closely related to human health [1]. It is well known that Se has an antioxidant effect in humans because it is an important part of the active center of glutathione peroxidase GSH-Px, which directly determines the level of hydrogen peroxide and lipid peroxide in cells [2]. It is reported that the content of Se in the human body needs to maintain a certain level, and excessive or lack of Se can lead to the occurrence of various diseases such as cirrhosis, cancer, diabetes and cardiovascular pathologies [3]. Therefore, it is very important to balance the human Se content. Diet is the main way for the body to obtain Se, but the survey found that there are problems with Se deficiency in two-thirds of the world [4]. So it is important to find more Se sources to improve the body's Se content to maintain human health. Compared with inorganic Se, organic Se has the advantages of safe eating, no side effects, high absorption efficiency and economic benefits [5]. Plants can accumulate Se in the environment and convert inorganic Se into organic Se, which can be considered as a green and healthy source of Se [6]. However, the accumulation ability of soil Se and the tolerance of high concentration Se vary greatly depending on the plant species. According to the plant's accumulation ability of soil Se, it can be divided into three categories: Se-accumulators, non-accumulators and secondary Se accumulators [7].

Liu et al. studied the physiological and ecological responses of *Astragalus sinicus* under different soil Se concentrations, and found that the Se content of *A. sinicus* increased with the increase of soil Se concentration, but high concentration of Se would affect the yield of *A. sinicus* and determine the best Se concentration for planting *A. sinicus* is 2.5 mg/kg [8]. Jiang et al. studied the effects of different Se concentrations on *Nicotiana tabacum* L. growth and Se accumulation and found that low concentrations of Se can promote the growth of *N. tabacum* and high concentrations of Se have a reaction, and the optimal concentration of Se for accumulating and planting is 6 mg/kg [9]. Different plants may respond differently to Se in the outside world because Se is involved in many complex metabolic processes in plants and different plants have different tolerance to Se, resulting in different results [10]. Therefore, studying the Se accumulation characteristics of different plants and screening more Se-accumulators as a source of Se supplementation is one of the research priorities at this stage. *Solanum alatum* is a variant of *Solanum nigrum* with a long history of food and medicinal use, which has a high nutritional content and high medicinal value and is distributed in most parts of China [11]. Studies on the cadmium stress response of *S. alatum* showed that cadmium stress inhibited the synthesis of *S. alatum* root length and chlorophyll, and increased the content of malondialdehyde and proline in leaves [12]. However, studies on the response of *S. alatum* to different concentrations of Se have not been reported. Therefore, in order to screen more Se sources, we used *S. alatum* was used as the material to study the effects of different concentrations of Se on *S. alatum* biomass and Se content.

2. Materials and methods

2.1 Materials collection
The seeds of *S. alatum* were collected from the farmland of Chengdu Campus of Sichuan Agricultural University. The *S. nigrum* seeds were sown in 25°C climate chamber in March 2018. The unpolluted soil was paddy soil, taken from farmland of Chengdu Campus of Sichuan Agricultural University (30° 71' N, 103° 86' E), pH 7.42, organic matter 31.73 g/kg, total nitrogen 1.05 g/kg, total phosphorus 0.37 g/kg, total potassium 25.71 g/kg, alkali nitrogen 56.13 mg/kg, available phosphorus 17.15 mg/kg, available potassium: 56.65 mg/kg. Soil properties were determined according to the method of reference [13].

2.2 Experimental design
The experiment was conducted in Chengdu Campus of Sichuan Agricultural University from April to May 2018. In March 2018, the unpolluted soil was air-dried and passed through a 5-mm sieve. 3 kg air-dried soil was weighed into each plastic pot (15 cm high, 18 cm in diameter), soaking uniformly Na_2SeO_3 by 0, 5, 10, 25, 50, 75, and 100 mg/kg respectively and balanced for 4 weeks. In April 2018, the same growing *S. alatum* with two real leaves were transplanted into the pots. Four *S. alatum* were planted in each pot. Five replicates per treatment and all pots were watered each day to keep the soil moisture about 80%. The distance between pots was 15 cm, and the pot position exchanged aperiodically to weaken the impact of the marginal effects. After 40 days, the whole *S. alatum* was harvested, washed with water
and then rinsed with distilled water for 3 times. After that, the material was divided into roots, stems and leaves, which were dried at 80 ° C until constant weight to weigh. The determination of selenium content of *S. alatum* was based on Munier-Lamy's method [14]. The translocation factor (TF) = Cd content in shoots / Cd content in roots [15].

2.3 Statistical analyses
Statistical analyses were conducted with statistical software of SPSS 17.0. Data were analyzed by one-way ANOVA with least significant difference at 5% confidence level.

3. Results and discussion

3.1 Biomass of S. alatum

Compared with the Se concentration of 0 mg/kg, all treatments significantly reduced the roots, stems and leaves of *S. alatum* biomass (Table 1). The order of Se concentrations in the roots, stems, shoots and whole plants of *S. alatum* biomass from large to small were all ranked: 0 mg/kg, 10 mg/kg, 5 mg/kg, 25 mg/kg, 50 mg/kg, 75 mg/kg, and 100 mg/kg. When the Se concentration started at 5 mg/kg, all parts of *S. alatum* biomass increased first and then decreased with the increase of Se concentration. When the concentration of Se was 100 mg/kg, the biomass of roots, stems, leaves, shoots and whole plants of *S. alatum* reached the lowest, which was 97.03% ($P < 0.05$), 99.40% ($P < 0.05$), 97.58% ($P < 0.05$), 98.24% ($P < 0.05$) and 98.00% ($P < 0.05$) lower than that of the control respectively. These results indicate that Se stress inhibits the growth of *S. alatum*, and the growth of *S. alatum* was almost stagnant under high concentration of Se stress.

Table 1. Biomass of *S. alatum*.

Selenium concentration (mg/kg)	Roots (g/plant)	Stems (g/plant)	Leaves (g/plant)	Shoots (g/plant)	Whole plants (g/plant)
0	0.337±0.02a	0.498±0.02a	0.869±0.08a	1.367±0.12a	1.704±0.16a
5	0.133±0.00bc	0.166±0.02bc	0.351±0.03c	0.517±0.05c	0.650±0.07c
10	0.201±0.01b	0.277±0.01b	0.601±0.04b	0.878±0.06b	1.079±0.10b
25	0.077±0.00cd	0.085±0.01cd	0.277±0.03c	0.362±0.03c	0.439±0.04cd
50	0.027±0.01cd	0.018±0.00d	0.040±0.01d	0.058±0.03d	0.085±0.01de
75	0.020±0.00cd	0.017±0.00d	0.030±0.00d	0.047±0.01d	0.067±0.00e
100	0.010±0.01d	0.003±0.00d	0.021±0.00d	0.024±0.00d	0.034±0.01e

Means with the same letter within each column are not significantly different at $p < 0.05$.

3.2 Selenium content of S. alatum

For the Se content of *S. alatum*, except for the Se concentration of 5 mg/kg, all the other treatments made the Se content of the roots, stems and leaves of *S. alatum* significantly higher than that of the control (Table 2). With the increase of Se concentration, the Se content of *S. alatum* roots and stems increased. The Se content of *S. alatum* leaves and shoots increased first and then decreased with the increase of Se concentration. When the concentration of Se was 50 mg/kg, the Se content of leaves and shoots of *S. alatum* reached the maximum ($P < 0.05$). Se content in *S. alatum* roots, stems leaves and shoots were in the ranges of 4.43-71.48 mg/kg, 0.79-40.21 mg/kg, 1.06-60.42 mg/kg and 0.97-51.43 mg/kg respectively under the Se stress. When the Se concentration started at 5 mg/kg, the TF of *S. alatum* increased first and then decreased with the increase of Se concentration. These results indicated that the Se concentration of roots and stems of *S. alatum* increased with the increase of soil Se concentration. The ability to transfer Se to the shoots of *S. alatum* increased first and then decreased with the increase of Se concentration.

Table 2. Selenium content of *S. alatum*.

Selenium concentration (mg/kg)	Roots (mg/kg)	Stems (mg/kg)	Leaves (mg/kg)	Shoots (mg/kg)	TF
0	0.00±0.00e	0.00±0.00e	0.00±0.00c	0.00±0.00d	-
5	4.43±0.09e	0.79±0.04e	1.06±0.01c	0.97±0.03d	0.11
10	21.91±0.44d	12.42±0.31d	17.43±0.26bc	15.85±0.28cd	0.68
25	40.94±0.87c	23.77±0.53c	33.67±0.32b	31.35±0.41bc	0.89
50	61.63±1.83b	31.46±1.40b	60.42±1.03a	51.43±1.07a	0.63
75	64.90±2.14ab	33.26±1.49b	33.17±1.58b	33.19±1.50b	0.53

100	71.48±3.26a	40.21±2.62a	21.84±2.65bc	24.17±3.25bc	0.31

Means with the same letter within each column are not significantly different at $p < 0.05$.

3.3 Selenium accumulation of S. alatum

For the Se accumulation of *S. alatum*, the Se accumulation of roots, stems and leaves increased first and then decreased with the increase of Se concentration (Table 3). At a Se concentration of 10 mg/kg, the Se accumulation of roots, stems, leaves, shoots and whole plants in *S. alatum* reached its maximum and was significantly higher than other treatments ($P < 0.05$). Compared with the Se concentration of 5 mg/kg, Se concentration of 10 mg/kg increased the Se accumulation of roots, stems and leaves of *S. alatum* by 86.63%, 96.19% and 96.45% respectively. Additionally, the order of Se concentrations in the shoots and whole plants of *S. alatum* Se accumulation from large to small were both ranked: 10 mg/kg, 25 mg/kg, 50 mg/kg, 75 mg/kg, 100 mg/kg, 5 mg/kg, and 0 mg/kg. Se accumulation in *S. alatum* shoots and whole plants were in the range of 0.503-13.915 μg/plant and 1.089-18.319 μg/plant respectively under the Se stress. These results indicated that the accumulation of Se by *S. alatum* differs depending on the difference in Se concentration in the environment. In all treatments, when the concentration of Se was 10 mg/kg, the Se accumulation of roots, stems and leaves was the highest, which is considered to be the most suitable concentration for *S. alatum* planting. Although the high concentration of Se stress significantly increased the Se content of each part of *S. alatum*, the Se accumulation of *S. alatum* decreased with a significant inhibition of the growth of *S. alatum*.

Table 3. Selenium accumulation of *S. alatum*.

Selenium concentration (mg/kg)	Roots (μg/plant)	Stems (μg/plant)	Leaves (μg/plant)	Shoots (μg/plant)	Whole plants (μg/plant)
0	0.000±0.00c	0.000±0.00e	0.000±0.00d	0.000±0.00d	0.000±0.00d
5	0.589±0.03c	0.131±0.01d	0.372±0.01d	0.503±0.02d	1.089±0.04cd
10	4.404±0.27a	3.440±0.14a	10.475±0.29a	13.915±0.49a	18.319±0.72a
25	3.152±0.14b	2.020±0.10b	9.327±0.21b	11.347±0.31b	14.499±0.45b
50	1.664±0.05c	0.566±0.02c	2.417±0.05c	2.983±0.07c	4.647±0.18c
75	1.298±0.05c	0.565±0.02c	0.995±0.04c	1.560±0.06c	2.858±0.10c
100	0.715±0.04c	0.121±0.01d	0.459±0.04c	0.580±0.06c	1.295±0.14c

Means with the same letter within each column are not significantly different at $p < 0.05$.

4. Conclusions

This study showed that different concentrations of selenium stress had different effects on the biomass and selenium content of *Solanum alatum*. For the biomass of *S. alatum*, all selenium treatments significantly reduced the biomass of each part of *S. alatum* and the biomass of *S. alatum* decreased with the increase of selenium concentration. High concentration of selenium inhibited the growth of *S. alatum* more significantly, when the concentration of Se was 100 mg/kg, the biomass of roots, stems, leaves, shoots and whole platnts of *S. alatum* reached the lowest, which was 97.03%, 99.40%, 97.58%, 98.24% and 98.00% lower than that of the control respectively. In addition, under the selenium stress, the biomass of each part of *S. alatum* reached the maximum when the concentration of selenium was 10 mg/kg, which indicated that the inhibition of *S. alatum* was the least when the concentration of selenium was 10 mg/kg. For the selenium content of *S. alatum*, with the increase of selenium concentration, the selenium content of roots and stems in *S. alatum* increased. The selenium content of *S. alatum* leaves and shoots increased first and then decreased with the increase of selenium concentration. Se content in *S. alatum* roots, stems, leaves and shoots were in the ranges of 4.43-71.48 mg/kg, 0.79-40.21 mg/kg, 1.06-60.42 mg/kg and 0.97-51.43 mg/kg respectively under the selenium stress. When the selenium concentration started at 5 mg/kg, the TF of *S. alatum* increased first and then decreased with the increase of selenium concentration. These results indicated that selenium stress would increase the ability to accumulate and transfer selenium in soil. In addition, the selenium accumulation of each part of *S. alatum* increased first and then decreased with the increase of selenium concentration. Selenium accumulation in *S. alaum* shoots and whole plants were in the ranges of 0.503-13.915 μg/plant and 1.089-18.319 μg/plant respectively. In all treatments, when the concentration of selenium was 10 mg/kg, the selenium accumulation of roots, stems and leaves was the highest. All these results indicated that selenium stress had a significant inhibitory effect on the growth of *S. alatum* and the growth of *S. alatum* was almost stagnant under high concentration of selenium stress. In all treatments, only the selenium concentration of 10 mg/kg had little effect on the biomass of *S. alatum*. When the concentration of selenium was 10 mg/kg, the selenium accumulation of each part of *S. alatum* reached the maximum. Therefore, *S. alatum* could grow under selenium stress of 10 mg/kg.

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