Effects of Different Selenium Concentrations on Photosynthetic Pigment Contents of *Solanum nigrum*

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Abstract. A pot experiment was carried out to study effects of different selenium concentrations (0, 5, 10, 25, 50, 75, and 100 mg/kg) on the photosynthetic pigment contents of *Solanum nigrum*. The results showed that all concentrations of selenium inhibited the chlorophyll a, chlorophyll b and carotenoid contents of *S. nigrum*. The selenium concentrations order of *S. nigrum* chlorophyll a, chlorophyll b and total chlorophyll contents from large to small were all ranked: 0 mg/kg, 10 mg/kg, 25 mg/kg, 5 mg/kg, 50 mg/kg, 75 mg/kg, and 100 mg/kg. Compared with the 0 mg/kg, only the selenium concentration of 10 mg/kg had little effect on the chlorophyll b and carotenoid contents of *S. nigrum*. These results indicated that high concentrations of selenium stress have significant inhibitory effects on the photosynthetic pigment contents of *S. nigrum*, which were not conducive to the growth of *S. nigrum*. When the concentration of selenium is 10 mg/kg, the inhibitory effects on the photosynthetic pigment contents of *S. nigrum* were the lowest.

1. Introduction
Selenium (Se) is an indispensable trace element in the human body, which is a significant component of various active enzymes, amino acids and polysaccharides [1]. Se participates in the normal immune function of the body and has important physiological functions such as protecting cardiovascular, anti-cancer and promoting growth [2]. According to the survey, 72% of counties (cities) in China lack Se to varying degrees, of which 1/3 are severely deficient in Se, which leads to the general lack of Se nutrient elements in animal husbandry and agriculture [3]. Studies have found that local diseases such as Kashin-Beck disease are associated with low levels of Se [4-5]. So it is of great significance to find a safe and efficient source of Se. Plants are producers of ecosystem that could convert organic Se into inorganic Se and accumulate in the body through the food chain [6]. Therefore, reasonable improvement of Se levels in agricultural products can be considered as an important way to supplement the needs of human Se nutrition. Additionally, Se and plant stress resistance are also closely related, which can effectively increase the plant's resistance to cold, drought, high light, water, salt and heavy metals [7]. Plants can be divided into three types: Primary Se accumulator, Secondary Se accumulator and Non-Se accumulator based on their ability to accumulate Se in soil according to Rosenfeld and Beath [8]. Screening for more Se-accumulate plants is important for reducing the risk...
of disease in Se-deficient areas. Photosynthesis is the basis of all life activities of plants, and 95% of plant dry matter comes from photosynthesis [9]. It is reported that low concentration of Se can significantly promote the content of light and pigment content in plant leaves, and the opposite high concentration of Se has a significant inhibitory effect on it, and the higher the concentration of Se, the more obvious the inhibition effect [10]. Zhang et al. found that Se treatment could not only effectively improve the photosynthesis rate (Pn), intercellular CO₂ concentration (Ci) and transpiration efficiency (E) of rice, but also activate photosynthetic system by increasing Fv, Fm and Fv/Fm [11]. Diao et al. studied the effect of exogenous Se on tomato under salt stress. It was found that exogenous Se could regulate the antioxidant system of tomato to improve the resistance of tomato to salt stress and improve the photochemical efficiency of PSII, thus maintaining high Photosynthetic rate [12].

**Solanum nigrum** is a one-year or perennial herb with a variety of medicinal properties and is distributed in most parts of China [13]. It was found that *S. nigrum* is a cadmium hyperaccumulator, and its growth is significantly inhibited under high cadmium stress [14]. However, the effects of Se on photosynthesis of *S. nigrum* have not yet been reported. Therefore, in order to screen more Se sources to alleviate the harm of low Se, we used *S. nigrum* as the material to study the effects of different concentrations of Se on *S. nigrum* photosynthetic pigment contents.

### 2. Materials and methods

#### 2.1 Materials collection

The seeds of *S. nigrum* 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 physicochemical properties were determined according to the method of reference [15].

#### 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 Na₂SeO₃ by 0, 5, 10, 25, 50, 75, 100 mg/kg respectively and balanced for 4 weeks. In April 2018, the same growing *S. nigrum* with two real leaves were transplanted into the pots. Four *S. nigrum* 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 upper mature leaves of *S. nigrum* were collected to determine the photosynthetic pigment (chlorophyll a, chlorophyll b and carotenoid) contents [16].

#### 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 Chlorophyll a content of *S. nigrum*

For the content of chlorophyll a, all treatments significantly reduced the chlorophyll a content of *S. nigrum* (Figure 1). When the Se concentration started at 10 mg/kg, the chlorophyll a content of *S. nigrum* decreased with increasing Se concentration. In all treatments, the Se concentration of 100 mg/kg resulted in the lowest chlorophyll a content of the *S. nigrum* (*P < 0.05*).
Figure 1. Chlorophyll a content of S. nigrum. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test ($p < 0.05$).

### 3.2 Chlorophyll b content of S. nigrum

For the content of chlorophyll b, except the Se concentration of 10 mg/kg had no significant effect on the chlorophyll b content of S. nigrum, other Se concentrations all reduced the chlorophyll b content of S. nigrum (Figure 2). When the Se concentration started at 10 mg/kg, the content of S. nigrum chlorophyll b decreased with increasing Se concentration. The Se concentrations order of S. nigrum chlorophyll b content from large to small was ranked: 0 mg/kg, 10 mg/kg, 25 mg/kg, 5 mg/kg, 50 mg/kg, 75 mg/kg, and 100 mg/kg. In all treatments, the Se concentration of 100 mg/kg resulted in the lowest chlorophyll b content of the S. nigrum ($P < 0.05$).

Figure 2. Chlorophyll b content of S. nigrum. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test ($p < 0.05$).

### 3.3 Carotenoid content of S. nigrum

For the content of carotenoid, except the Se concentration of 10 mg/kg and Se concentration of 25 mg/kg had no significant effect on the carotenoid content of S. nigrum, other Se concentrations all significantly reduced the carotenoid content of S. nigrum (Figure 3). When the Se concentration started at 25 mg/kg, the content of S. nigrum carotenoid decreased with increasing Se concentration. Among all treatments, the Se concentration of 100 mg/kg resulted in the lowest carotenoid content of the S. nigrum ($P < 0.05$).
Figure 3. Carotenoid content of *S. nigrum*. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test (\(p < 0.05\)).

### 3.4 Total chlorophyll content of *S. nigrum*
For the total chlorophyll content, all treatments significantly reduced the total chlorophyll content of *S. nigrum* (Figure 4). When the Se concentration started at 10 mg/kg, the total chlorophyll content of *S. nigrum* decreased with increasing of Se concentration. The Se concentrations order of *S. nigrum* total chlorophyll content from large to small was ranked: 0 mg/kg, 10 mg/kg, 25 mg/kg, 5 mg/kg, 50 mg/kg, 75 mg/kg, and 100 mg/kg. In all treatments, the Se concentration of 100 mg/kg resulted in the lowest total chlorophyll content of the *S. nigrum* (\(P < 0.05\)).

Figure 4. Total Chlorophyll content of *S. nigrum*. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test (\(p < 0.05\)).

### 3.5 Chlorophyll a/b of *S. nigrum*
Compared with the Se concentration of 0 mg/kg, only when the concentration of Se was 75 mg/kg, the chlorophyll a/b of *S. nigrum* increased, other treatments all reduced the chlorophyll a/b of *S. nigrum* to different extents (Figure 5). The Se concentrations order of *S. nigrum* chlorophyll a/b from large to small was ranked: 75 mg/kg, 0 mg/kg, 50 mg/kg, 10 mg/kg, 25 mg/kg, 5 mg/kg, and 100 mg/kg. In all treatments, the Se concentration of 100 mg/kg resulted in the lowest chlorophyll a/b of the *S. nigrum* (\(P < 0.05\)).
Figure 5. Chlorophyll a/b of *S. nigrum*. Different lowercase letters indicate significant differences based on one-way analysis of variance in SPSS 17.0 followed by the least significant difference test (*p* < 0.05).

4. Conclusions

This study showed that different concentrations of selenium stress had different effects on the photosynthetic pigment contents of *S. nigrum*. For *S. nigrum* chlorophyll a and carotenoid contents, all concentrations of selenium treatments significantly reduced the chlorophyll a, total chlorophyll and carotenoid contents of *S. nigrum*. The selenium concentrations order of *S. nigrum* chlorophyll a, chlorophyll b and total chlorophyll contents from large to small were all ranked: 0 mg/kg, 10 mg/kg, 25 mg/kg, 5 mg/kg, 50 mg/kg, 75 mg/kg, and 100 mg/kg. When the selenium concentration started at 5 mg/kg, the chlorophyll a, chlorophyll b and total chlorophyll contents of *S. nigrum* increased first and then decreased with the increase of selenium concentration. When the selenium concentration was 100 mg/kg, the chlorophyll a, total chlorophyll content and chlorophyll a/b of *S. nigrum* were significantly lower than other treatments. Compared with the 0 mg/kg, except the selenium concentration of 5 mg/kg, 10 mg/kg and 25 mg/kg had little significant effect on the chlorophyll b content of *S. nigrum*, other treatments all significantly reduced it. In addition, only the selenium concentration of 10 mg/kg and 25 mg/kg had little significant effect on the carotenoid content of *S. nigrum*, other treatments all significantly reduced it. These results indicated that high concentrations of selenium stress had a significant inhibitory effect on the photosynthetic pigment contents of *S. nigrum*, which were not conducive to the growth of *S. nigrum*. Therefore, *S. nigrum* could grow under selenium stress of 10 mg/kg.

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