Study on Selenium Accumulation Characteristics of Radish

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Abstract. In order to study the effects of different concentrations of selenium on the selenium accumulation characteristics of radish, we used the pot experiment to study effects of different selenium concentrations (0, 5, 10, 25, 50, 75, and 100 mg/kg) on the biomass and selenium content of radish. The results showed that selenium stress inhibited the biomass of radish and the higher the concentration of selenium and the stronger the inhibition of radish growth. In addition, the selenium content of radish increased with the increase of selenium concentration. Selenium content in radish roots, tubers and leaves were in the ranges of 21.71-346.64 mg/kg, 11.05-251.38 mg/kg, and 8.34-210.91 mg/kg respectively under the selenium stress. Compared with the selenium concentration of 0 mg/kg, all treatments significantly increased the tubers, leaves, shoots and whole plants of radish selenium accumulation. In all treatments, when the concentration of selenium was 25 mg/kg, the selenium accumulation of each part of radish reached the maximum and the selenium accumulation of radish in shoots and whole plants reached 111.96 μg/plant and 119.21 μg/plant respectively. In a word, radish has the strongest accumulation ability of selenium in soil when the concentration of selenium is 25 mg/kg, which can be considered as the best selenium concentration to increase the selenium content of radish.

1. Introduction

Selenium (Se) is one of the trace elements and plays an extremely important role in human health [1]. It is well known that Se is the main synthetic precursor of GSH-Px, which could affect the stress resistance of the human body [2-3]. Lack of Se can directly harm human health, and more than 40 diseases have been found to be associated with Se deficiency, such as Keshan, cancer, cardiovascular disease and cataract [4-5]. There are many areas in the world where Se deficiency exists, and the survey found that the average Se intake of Chinese adults is much lower than the standard content, which indicates that there is a risk of low Se in most parts of China [6]. Therefore, it is important to find more Se sources to improve the body's Se content to maintain human health. Additionally, studies have shown that Se plays a vital role not only in humans but also has many important functions in plants [7]. External stresses such as cold, drought, high light, excessive water, salinity, etc. can lead to the accumulation of ROS in plants. Increased ROS production poses a threat to plants and hinders the normal metabolism of plants [8]. Recently, study has found that the addition of exogenous Se could reduce the production of excessive ROS, which can effectively improve the resistance of plants to external stress [9]. Up to now, research has begun to use Se fertilizer to increase the Se content of edible parts of plants while improving the stress resistance of plants [10]. For example, it has been proved that the addition of exogenous Se under heavy metal stress could significantly reduce the accumulation of lead and cadmium in lettuce and increase the enrichment of Se in lettuce [11]. Compared with inorganic Se, organic Se is more easily absorbed by the body and is less toxic [12]. Plants can convert inorganic Se in the natural environment into organic Se and accumulate in plants, so it is very important to screen more Se accumulator. Radish (*Raphanus sativus* L.) is a highly nutritious plant cultivated all over the world, which tubers can be eaten as vegetables [13]. It has the advantages of extensive management, strong growth and developed roots. Wang et al. applied different concentrations of Na_2SeO_3 on the radish leaf surface and found that the Se content and the conversion rate of organic Se in various forms of radish increased with the increase of Se content. In addition, the total sugar, carotene and calcium, magnesium, iron and other elements of radish were increased under the treatment of Se [14]. This indicates that radish has a very high Se accumulation potential. However, the effects of different Se application methods on plant Se accumulation are quite different. The effect of addition different concentrations of Na_2SeO_3 to soil on the Se accumulation characteristics of radish has not been reported. Therefore, in order to find more ways to improve the Se content of radish, this experiment studied the effects of adding different concentrations of Se on the biomass and Se content of radish.

2. Materials and methods

2.1 Materials collection

The test material is radish, the variety is "golden carrot", belonging to the four season variety, early red radish, the leaves were reddish and main vein was red. 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, total selenium 0.35 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 November 2017 to February 2018. In August 2017, 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, 100 mg/kg respectively and balanced for 4 weeks. In November 2017, the same growing radishes with two real leaves were transplanted into the pots. Four radishes were planted in each pot. Three replicates per treatment and all pots were watered each day to keep the soil moisture about 80%. The distance between pots was 10 cm, and the pot position exchanged aperiodically to weaken the impact of the marginal effects. After 60 days, the whole radish was harvested, washed with water and then rinsed with distilled water for 3 times. After that, the material was divided into roots, tubers and leaves, which were dried at 80 ° C until constant weight to weigh. The determination of selenium content of radish was based on Munier-Lamy's method [16]. The translocation factor (TF) = Cd content in shoots / Cd content in roots [17].

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 radish

Compared with the Se concentration of 0 mg/kg, all treatments significantly reduced the roots, tubers and leaves of radish biomass ($P < 0.05$). The order of Se concentrations in the roots, tubers, shoots and whole plants of radish biomass from large to small were all ranked: 0 mg/kg, 5 mg/kg, 10 mg/kg, 25 mg/kg, 50 mg/kg, 75 mg/kg, and 100 mg/kg (Table 1). All parts of radish biomass increased with the increase of Se concentration. When the concentration of Se was 100 mg/kg, the biomass of roots, tubers, leaves, shoots and whole plants of radish reached the lowest, which was 87.10% ($P < 0.05$), 96.81% ($P < 0.05$), 92.72% ($P < 0.05$), 93.98% ($P < 0.05$) and 93.66% ($P < 0.05$) lower than that of the control respectively. These results indicated that the growth of radish is inhibited by Se stress, and the radish growth is more inhibited with the increase of Se concentration.

Table 1. Biomass of radish.

Selenium concentration (mg/kg)	Roots (mg/kg)	Tubers (mg/kg)	Leaves (mg/kg)	Shoots (mg/kg)	Whole plants (mg/kg)
0	0.093±0.004a	0.595±0.011a	1.347±0.016a	1.942±0.004a	2.035±0.182a
5	0.084±0.005b	0.561±0.005b	1.302±0.010b	1.863±0.015b	1.947±0.146ab
10	0.065±0.004c	0.501±0.014c	1.247±0.017c	1.748±0.032c	1.813±0.117bc
25	0.059±0.003c	0.459±0.015d	1.167±0.013d	1.626±0.028d	1.685±0.094c
50	0.033±0.002d	0.053±0.004e	0.369±0.009e	0.442±0.005e	0.455±0.002d
75	0.024±0.005e	0.031±0.001ef	0.193±0.005f	0.224±0.006f	0.248±0.010de
100	0.012±0.002f	0.019±0.001f	0.098±0.003g	0.117±0.004g	0.129±0.005e

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

3.2 Selenium content of radish

For the Se content of radish, except for the Se concentration of 5 mg/kg, all the other treatments made the Se content of the roots, tubers and leaves of radish significantly higher than that of the control ($P < 0.05$). The Se content of radish roots, tubers, leaves and shoots increased with the increase of Se concentration (Table 2). When the concentration of Se was 100 mg/kg, the Se content of radish roots, tubers, leaves and shoots reached the maximum, which was 7905.54% ($P < 0.05$), 7957.05% ($P < 0.05$), 7858.87% ($P < 0.05$) and 7668.57% ($P < 0.05$) higher than that of the control respectively. Compared with the Se concentration of 0 mg/kg, Se reduced the TF of radish. These results indicated that the ability of radish to absorb Se increase with the increase of Se concentration, but the ability to transfer Se to the shoots is reduced.

Table 2. Selenium content of radish.

Selenium concentration (mg/kg)	Roots (mg/kg)	Tubers (mg/kg)	Leaves (mg/kg)	Shoots (mg/kg)	TF
0	4.33±0.23f	3.12±0.16f	2.65±0.00e	2.80±0.00e	0.647
5	21.71±1.16f	11.05±0.55f	8.34±0.01e	9.16±0.03e	0.422
10	52.51±2.94e	26.58±1.46e	14.42±0.20d	17.91±0.23d	0.341
25	122.85±6.34d	73.24±3.27d	67.13±0.34d	68.86±0.30d	0.561
50	203.75±10.09c	122.17±6.11c	107.03±1.31c	108.93±1.87c	0.535
75	286.93±11.54b	200.03±11.27b	151.46±1.48b	158.17±1.45b	0.551
100	346.64±15.76a	251.38±12.69a	210.91±2.55a	217.52±3.46a	0.628

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

3.3 Selenium accumulation of radish

For the Se accumulation of radish, the Se accumulation of tubers, leaves, shoots and whole plants increased first and then decreased with the increase of Se concentration (Table 3). Compared with the Se concentration of 0 mg/kg, all treatments significantly increased the tubers, leaves, shoots and whole plants of radish Se accumulation ($P < 0.05$). At a Se concentration of 25 mg/kg, the Se accumulation of roots, tubers, leaves, shoots and whole plants of radish reached the maximum, which was 1712.50% ($P < 0.05$), 1707.53% ($P < 0.05$), 2094.40% ($P < 0.05$), 1961.88% ($P < 0.05$) and 1944.77% ($P < 0.05$) higher than that of the control respectively. Additionally, the orders of Se concentrations in the shoots and whole plants of radish Se accumulation from large to small were both ranked: 25 mg/kg, 50 mg/kg, 75 mg/kg, 10 mg/kg, and 100 mg/kg 5 mg/kg, 0 mg/kg. Se accumulation in radish shoots and whole plants were in the range of 17.06-111.96 μg/plant and 18.88-119.21 μg/plant respectively under the Se stress. These results indicated that the accumulation of Se by radish differs depending on the difference in Se concentration in the environment. Although high concentration of Se stress could effectively increase the Se content of various parts of radish, radish almost stopped growing under high concentration of Se stress. In all treatments, when the concentration of Se was 25 mg/kg, the each part of radish Se accumulation was the highest, which is considered to be the most suitable concentration for radish planting.

Table 3. Selenium accumulation of radish.

Selenium concentration (mg/kg)	Roots (μg/plant)	Tubers (μg/plant)	Leaves (μg/plant)	Shoots (μg/plant)	Whole plants (μg/plant)
0	0.40±0.00d	1.86±0.00e	3.57±0.17f	5.43±0.21f	5.83±0.19f
5	1.82±0.08cd	6.20±0.27c	10.86±0.52e	17.06±0.85e	18.88±0.94e
10	3.41±0.24bc	13.32±0.12b	17.98±1.03d	31.30±1.45c	34.71±1.77cd
25	7.25±0.11a	33.62±1.61a	78.34±4.28a	111.96±5.74a	119.21±5.40a
50	6.72±0.32a	6.48±0.32c	39.49±2.16b	45.97±3.01b	52.69±2.73b
75	6.89±0.25a	6.20±0.35c	29.23±1.44c	35.43±2.27c	42.32±2.11c
100	4.16±0.44b	4.78±0.41d	20.67±1.35d	25.45±1.55d	29.61±1.72d

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 radish. For the biomass of radish, all selenium treatments significantly reduced the biomass of each part of radish and the order of selenium concentrations in the roots, tubers, shoots and whole plants of radish biomass from large to small were all ranked: 0 mg/kg, 5 mg/kg, 10 mg/kg, 25 mg/kg, 50 mg/kg, 75 mg/kg, 100 mg/kg. When the concentration of selenium was 100 mg/kg, the biomass of roots, tubers, leaves, shoots and whole plants of radish reached the lowest, which was 87.10% ($P < 0.05$), 96.81% ($P < 0.05$), 92.72% ($P < 0.05$), 93.98% ($P < 0.05$) and 93.66% ($P < 0.05$) lower than that of the control respectively. For the selenium content of radish, the selenium content of each part of radish increased with the increase of selenium concentration. When the concentration of selenium was 100 mg/kg, the selenium content of radish roots and shoots reached the maximum, which was 7905.54% ($P < 0.05$) and 7668.57% ($P < 0.05$) higher than that of the control respectively. Compared with the Se concentration of 0 mg/kg, selenium stress reduced the TF of radish. These results indicated that selenium stress would increase the ability to accumulate selenium in soil but inhabit the ability to transfer selenium to shoots. In addition, the selenium accumulation of tubers, leaves, shoots and whole plants of radish increased first and then decreased with the increase of selenium concentration. Selenium accumulation in radish shoots and whole plants were in the ranges of 17.06-111.96 μg/plant and 18.88-119.21 μg/plant respectively under the selenium stress. In all treatments, when the concentration of selenium was 25 mg/kg, each part of radish selenium accumulation reached the maximum. All these results indicated that selenium stress had a significant inhibitory effect on the growth of radish and the higher the concentration of selenium, the stronger the inhibition of radish growth. When the concentration of selenium was 25 mg/kg, the selenium accumulation of each part of radish reached the maximum. Therefore, radish has the strongest accumulation ability of selenium in soil when the concentration of selenium is 25 mg/kg, which can be considered as the best selenium concentration to increase the selenium content of radish.

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