Brazilian Journal of Biology®

ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

Original Article

The effectiveness of the use of selenium-containing top dressing in the cultivation of radish

A eficácia do uso de cobertura contendo selênio no cultivo de rabanete

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Abstract

Vegetable crops of the Brassicaceae family have the ability to include the necessary trace element selenium (Se) in the composition of organic compounds such as selenoproteins, in addition, they have important properties for human health based on the content of selenium. In our work, we investigated the effect of non-root processing of vegetating radish plants on the quality of finished products. The research results showed that the selenium content in the product part of plants significantly increased with an increase in the concentration of this element in the working solution. The dry matter content also increased, while its greatest amount was observed at lower concentrations of Se in the working solution. The use of non-root treatment with a selenium-containing solution on vegetative plants led to a significant decrease in the content of ascorbic acid and nitrates, and the decrease in the amount of nitrates in radish root crops was inversely dependent on the concentration of selenium in the working solution.

Keywords: radish, root vegetables, trace elements, selenium, non-root processing, product quality.

Resumo

As hortaliças da família Brassicaceae têm a capacidade de incluir o oligoelemento selênio (Se) necessário na composição de compostos orgânicos como as selenoproteínas, além disso, possuem propriedades importantes para a saúde humana com base no teor de selênio. Em nosso trabalho, investigamos o efeito do processamento não radicular de plantas de rabanete vegetantes na qualidade dos produtos acabados. Os resultados da pesquisa mostraram que o teor de selênio na parte do produto das plantas aumentou significativamente com o aumento da concentração desse elemento na solução de trabalho. O teor de matéria seca também elevou, enquanto sua maior quantidade foi observada em menores concentrações de Se na solução de trabalho. O uso de tratamento não radicular com uma solução contendo selênio em plantas vegetativas levou a uma diminuição significativa no teor de ácido ascórbico e nitratos, e a diminuição na quantidade de nitratos nas raízes de rabanete foi inversamente dependente da concentração de selênio na solução de trabalho.

Palavras-chave: rabanete, vegetais de raiz, oligoelementos, selênio, processamento não-raiz, qualidade do produto.

1. Introduction

People's health directly depends on the quality of the food consumed. Since plant products, including vegetables, are an integral part of the human diet, much attention is paid by researchers not only to obtaining high yields, but also to its mineral value, that is, the content of both macro- and microelements in the food part.

According to various authors, the content of trace elements in plants ranges from $1 \cdot 10^{-3}$ to $1 \cdot 10^{-5}$% (Sheudzen, 2003). The content of macronutrients and the diversity of the microelement composition of cultivated plants is due not only to the specific and varietal characteristics of the plants themselves, but also to the content of mobile, that is, forms of elements and organic matter available to plants in arable soils, which, in turn, depends on the underlying rocks (Protasova, 2005; Borisov et al., 2021; Zhevnerov et al., 2021; Borisov et al., 2022). In addition, agrotechnics of crop cultivation and the use of microelement fertilizing play an essential role in the formation of the crop (Eliseev et al., 2011; Eliseeva and Eliseev, 2012; Eliseev and Eliseeva, 2016).

Trace elements in plants play a significant role, which is associated with their participation in various biochemical and physiological processes. The functions of vitamins, hormones, and enzymes depend on the content of trace elements. They influence the synthesis of organic substances, which ultimately affects the productivity of crops and the quality of the products obtained (Eliseeva et al., 2017; Eliseeva et al., 2019; Chen et al., 2023; Huang et al., 2023). Each trace element has its own

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Received: August 23, 2023 – Accepted: October 10, 2023

specific role, however, at the same time they can perform similar functions from the point of view of biochemistry.

One of the trace elements, the content of which in plants is given great attention, is selenium (Eliseeva, 2007; Vikhreva et al., 2011; Eliseeva and Eliseev, 2019; Alexandrovskaya et al., 2020; Seregina and Makarskaya, 2021; Zou et al., 2022; Cipriano et al., 2022). This element in the human body participates in various biochemical processes and is very important for its normal functioning. However, in doses exceeding 200 micrograms per day, it is toxic (Gmoshinsky et al., 2000; Tutelyan et al., 2002; Baraboĭ and Shestakova, 2004; Deryabina et al., 2006). It should be borne in mind that with a lack of selenium in the human body, pathologies develop, and in men with selenium intake less than 21 mcg per day, and in women – less than 16 mcg per day (Ursini et al., 1999). In general, selenium deficiency in an adult is noted with a decrease in its concentration in blood plasma of less than 60 mcg · l^{-1} (Reshetnik and Parfenova, 2000). Selenium compounds are antioxidants and protect the cells of the human body from the harmful effects of free radicals (Torshin et al., 1996; Gmoshinsky et al., 2000; Hu et al., 2021). Due to the participation of this trace element in various physiological processes, there is a significant increase in the active life of cells, strengthening of immunity, since selenium contributes to the formation of protein molecules with protective properties. Sufficient availability of this trace element reduces the likelihood of cardiovascular diseases. In addition, selenium participates in the biosynthesis of nucleic acids, and also affects the stability of the nervous system, visual acuity and concentration. An important role of selenium is in the process of maturation of male germ cells, in the work of the thyroid and pancreas (Fleet, 1997; Scott et al., 1998; Johnson and Porter, 1997; Baraboĭ and Shestakova, 2004; Deryabina et al., 2006; Zou et al., 2022).

The biochemistry and physiology of selenium and sulfur have a lot in common. Different researchers have found that sulfur can be replaced by selenium in amino acids such as methionine and cysteine, as well as in the enzymes ferredoxin and galactosidase, that most plants synthesize selenistein, selenmethionine, selenmethionine selenoxide, etc. The use of selenium-containing top dressing has a positive effect on the formation of selenoproteins in plants and depends on the concentration of selenium in the solutions used (Klayman and Gunther, 1973; Brown and Shrift, 1982; Bollard, 1983; Gmoshinsky and Mazo, 2006; Zou et al., 2022). Bollard (1983) showed that selenium participates in the formation of chlorophyll, in the synthesis of tricarboxylic acids, in the metabolism of fatty acids, and selenium-derived analogues of sulfolipids were not found.

An important source of trace elements and, in particular, selenium are vegetable crops, which in experiments Torshin et al. (1995) they have shown great potential in the accumulation of this trace element. Also, in other work Torshin (1998) it is shown that under the conditions of the growing experiment, the introduction of sodium selenite into the soil at doses of 25-2500 mcg Se/kg allowed to obtain selenium enrichment of vegetable crops by 5-1600%. In the work of other researchers, data are given that when growing radishes without selenium in its root crops, depending on the granulometric composition of the soil, this element accumulates 56-187 mcg · kg^{-1} of dry weight, and 72 mcg · kg^{-1} in lettuce leaves on heavy soils. At the same time, the average Se content in vegetable crops ranges from 6 to 23 mcg · kg^{-1} of raw mass (Combs Junior and Combs, 1986; Eliseeva and Eliseev, 2007; Trolove et al., 2018; Cipriano et al., 2022; Cheng et al., 2022). Within the same limits, the safe content of selenium in plants for animals and humans is estimated (Neve and Favier, 1989; Hladun et al., 2013), and the accumulation of selenium in the aboveground parts of plants is higher than in the roots (Torshin et al., 1995).

The purpose of the research is to study the effect of non–root treatment of vegetative plants with sodium selenite solution on the chemical composition of radish root crops.

2. Objects and Methods of Research

In our research conducted on the basis of Russian State Agrarian University - Moscow Timiryazev Agricultural Academy, the effect of non-root treatment was studied (NRT) vegetative radish plants with sodium selenite solution on the quality indicators of finished products. The object of the study was a seed radish (*Raphanus sativus L.*) varieties Winter round black. Sowing was carried out on July 22 according to the scheme 50 + 20 × 25 cm. The area of the accounting plot 2 m^2. The feeding area of 1 plant was 875 cm^2, the plant density was 11.5 plant · m^{-2}. Sodium selenite solution (Na_2SeO_3) was used in four concentrations of 0.0005%, 0.001%, 0.002% and 0.005% Se. The experiment was carried out in 3-fold repetition according to the following scheme: NPK (background) – control option; NPK + NRT Se 0.0005%; NPK + NRT Se 0.001%; NPK + NRT Se 0.002%; NPK + NRT Se 0.005%. Nitroammophosca was introduced into the soil at the rate of 30 g/m^2 as a background macro fertilizer during sowing. Treatment with sodium selenite solution was carried out by spraying vegetative plants in the phase of mass molting of the root. In the background versions, the plants were treated with distilled water. Harvesting and evaluation of its quality was carried out in the phase of technical ripeness (October 2). The growing season was 70 days.

The dry matter content was determined by drying the crushed sample at 105 ° C to a constant air-dry mass. The content of dry soluble substances was determined by the refractometric method on the refractometer RL 3. The content of ascorbic acid was determined by the method of I.K. Murri. The nitrate content was determined by a potentiometric method using an ion-selective nitrate electrode on an Ecotest-2000 device. The selenium content was determined by atomic absorption spectrophotometry on the AAS QUANTUM-Z.ETA.

To calculate the smallest significant Fischer difference in the content of dry matter, dry soluble substances, ascorbic acid, the accumulation of nitrates and the trace element selenium in root crops, a dispersion analysis was performed using the STRAZ software package.

3. Research Results

Table 1 shows data on agrochemical analysis of sod-podzolic medium loamy soil on which radish was grown.

The soil on which the radish was grown is sufficiently cultivated, has a high supply of mobile forms of phosphorus and potassium, as well as an average supply of nitrogen, a slightly acidic reaction of the medium, is characterized by a low humus content, which is characteristic of soils of the Central Non-Chernozem region.

Such indicators of product quality as the content of dry matter, dry soluble substances, ascorbic acid, the accumulation of nitrates and the trace element selenium in root crops were studied.

The data presented in Table 2 show that foliar treatment of vegetative plants with sodium selenite solution in the studied concentrations did not significantly affect the accumulation of dry matter in radish root crops. However, there was a tendency to increase this indicator in variants with plant treatment compared to the background by 38-53%. At the same time, this indicator was the highest in the NPK+HO Se 0.0005% and NPK+HO Se 0.001% and amounted to 14.1%.

Differences in the accumulation of dry soluble substances according to the experimental variants in comparison with the background variant were insignificant, but there was a tendency to increase this indicator in radish root crops compared to the control by 5-20%, depending on the concentration of selenium in solution. Thus, the content of dry soluble substances in the NPK+ NRT Se 0.0005% was 7.1%. An increase in the dose of selenium to 0.005% led to an increase in the content of dry soluble substances to 8.5%.

The use of non-root treatment of vegetative radish plants with sodium selenite solution contributed to a significant decrease in the content of ascorbic acid in root crops, and a significant decrease in this indicator was observed only in comparison with the control variant (background). So, in the variants of the NPK+ NRT Se 0.0005% and NPK+ NRT Se 0.002%, this indicator decreased in comparison with the background, respectively, by 1.5 and 1.6 times and amounted to 26.66 mg · 100^{-1} g and 25.08 mg · 100^{-1}. In variants NPK+ NRT Se 0.001% и NPK+ NRT Se 0.005% concentration of ascorbic acid was at the level of 31.08 and 30.01 mg · 100^{-1} g, respectively, which is 1.3 times lower than the control value of this indicator. According to the variants of the experiment with the treatment of plants with sodium selenite, there were no significant differences in the content of ascorbic acid in root crops.

Non-root treatment of radish plants also led to a significant decrease in the nitrate content in all variants of the experiment. At the same time, with an increase in the concentration of Se in the solution, a decrease in the content of nitrates in root crops was observed. In the experience options NPK+ NRT Se 0.0005% и NPK+ NRT Se 0.001% of the nitrate content was 483.7 and 494.8 mg · kg^{-1} of crude mass, respectively, which is 1.6 times less than in the background version. With a further increase in the concentration of selenium in the solution (option NPK+ NRT Se 0.002%), there was a decrease in the nitrate content in root crops to 423.3 mg · kg^{-1} of raw mass. With an increase in the dose of selenium in the NPK+ NRT Se 0.005%, this indicator decreased by 3.2 times compared to the background and amounted to 241.9 mg · kg^{-1} of crude mass. It should be noted that an increase in the concentration of selenium in the solution also led to a significant decrease in the nitrate content in the variants of the NPK+ NRT Se 0.002% and NPK+ NRT Se 0.005% compared to NPK+ NRT Se 0.0005% and NPK+ NRT Se 0.001% by 12-14% and 50%, respectively.

Table 1. Agrochemical characteristics of the soil.

Humus, %	pH_{KCl}	Hydrolytic acidity, mg · 100^{-1} g of soil	Easily hydrolyzable nitrogen	P_2O_5	K_2O	Degree of saturation of soils with bases, %	Se, mcg · kg^{-1} of dry weight
			mg · kg^{-1} of soil				
2.7	6.3	0.89	84	271	194	93.7	212.97

Table 2. Chemical composition of products.

Variety	Experience option	Dry matter content, %	Content of dry soluble substances, %	Ascorbic acid content, mg 100^{-1}	Nitrate content, mg · kg^{-1}	Se content, mcg · kg^{-1} of dry weight
Winter round black	NPK (background)	9.2	7.0	40.04	778.6	209.05
	NPK+ NRT Se 0.0005%	14.1	7.1	26.66	483.7	240.59
	NPK+ NRT Se 0.001%	14.1	7.5	31.08	494.8	249.40
	NPK+ NRT Se 0.002%	12.7	7.4	25.08	423.3	243.75
	NPK+ NRT Se 0.005%	13.5	8.5	30.01	241.9	250.24
the smallest significant difference 05		1.6	0.7	6.6	57.8	10.32

The use of selenium as a non-root top dressing of radish plants led to an increase in the content of this trace element in root crops compared to the background version. The selenium content in the product part of plants was on average 1.2 times higher than in the control variant and lay in the range of 240.40-250.24 mcg · kg^{-1} of dry weight. The differences in the content of this trace element in the variants of the experiment with the treatment of plants with sodium selenite solution were insignificant.

4. Conclusion

Thus, the use of selenium-containing top dressing by means of non-root treatment of vegetative plants led to an increase in the concentration of selenium and a decrease in the content of ascorbic acid in the product part of radish plants, as well as to a decrease in the content of nitrates in root crops, which was inversely dependent on the concentration of selenium in the working solution.

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