
# Research Progress in Plant Selenium Enrichment

**Min-jing Wu [1], Si-yu Huang [2], Jia-qi Wu [3], Lin-Lin Tang [4], Yu-yan Guo [5], Ren-hua Huang [6]***
[1-6] College of Food and Biology, Jingchu University of Technology, Jingmen 448000, China

* Corresponding Author: **Ren-hua Huang**

**Article Info**
**ISSN (online):** 2582-7138
**Volume:** 06
**Issue:** 02
**March-April 2025**
**Received:** 09-02-2025
**Accepted:** 10-03-2025
**Page No:** 1272-1274

**Abstract**
Selenium (Se) is an essential micronutrient for human health, with soil availability determining plant uptake. Global distribution varies, with China having both deficient and selenium-rich regions. Selenate shows higher bioavailability than selenite due to weaker soil adsorption. Soil pH and organic matter critically influence selenium availability, with alkaline conditions favoring selenate. Fertilizer type and application timing affect plant uptake, with foliar selenate application during late growth stages being most effective. Optimizing soil properties and rhizosphere processes can enhance selenium absorption in crops like wheat, supporting biofortification strategies to address selenium deficiency.

**DOI:** https://doi.org/10.54660/.IJMRGE.2025.6.2.1272-1274

**Keywords:** selenium; availability; soil pH; enrichment

## 1. Introduction

Selenium (Se) is an essential trace element crucial for the survival of humans and animals. In recent years, research on selenium has increased significantly. Selenium is widely distributed in all human tissues and organs, participating in various metabolic activities and immune responses. It is regarded as the most important dietary antioxidant in the human body. Numerous studies have shown that selenium deficiency can lead to severe diseases, particularly concerning selenoproteins, which are associated with several human disorders, including cancer, diabetes, cardiovascular diseases, and immune system dysfunctions. However, excessive selenium intake can result in selenosis (selenium toxicity). Only appropriate selenium intake can enhance bodily functions, prevent diseases, and delay aging.

## 2. Content and distribution of selenium in soil

Selenium exhibits an uneven global distribution. While severe selenium-deficient areas exist worldwide (e.g.,the Keshan disease region in northwestern China), some regions are notably selenium-rich, such as Ziyang (Shanxi) and Enshi (Hubei) in China, parts of Colombia, South Dakota (USA), Israel, Russia, and Canada. China is largely selenium-deficient, with nearly half of its soils lacking adequate selenium. The threshold values for total selenium content in soil are classified as:

- Deficient (<0.125 $mg \cdot kg^{-1}$)
- Marginal (0.125–0.175 $mg \cdot kg^{-1}$)
- Adequate (0.175–0.45 $mg \cdot kg^{-1}$)
- Selenium-rich (0.45–2.0 $mg \cdot kg^{-1}$)
- High-selenium (2.0–3.0 $mg \cdot kg^{-1}$)
- Selenium-toxic (>3.0 $mg \cdot kg^{-1}$)

A low-selenium belt (average content 0.1 $mg \cdot kg^{-1}$) stretches diagonally from northeast to southwest China. Hu *et al.* revealed that this belt forms a discontinuous, zonal distribution extending from eastern Inner Mongolia to southwestern Qinghai, southern Xinjiang, and the Tibetan Plateau [1].

## 3. Forms of selenium in soil

Based on solubility and binding capacity in soil, selenium can be sequentially categorized into five forms:

- Water-soluble selenium (SOL-Se)
- Exchangeable and carbonate-bound selenium (EXC-Se)
- Iron-manganese oxide-bound selenium (FMO-Se)
- Organic matter-bound selenium (OM-Se)
- Residual selenium (RES-Se)

Their bioavailability gradually decreases in this order. SOL-Se and EXC-Se exist in a free state within the soil solution or are weakly adsorbed on particle surfaces, making them readily absorbable and utilizable by plants. Thus, these two forms are collectively termed" soil available selenium" [2]. OM-Se represents the sum of organic selenium compounds adsorbed onto organic matter and inorganic selenium coordinated with organic molecules or incorporated into organic matter. Although it exhibits relatively low bioavailability, OM-Se can be released under certain conditions, demonstrating potential selenium-supplying capacity. Therefore, it is regarded as "potentially available selenium" in soil.

## 4. Influence of selenium species on selenium availability

Selenate and selenite are two important types of inorganic selenium fertilizers. Due to the strong adsorption and fixation of selenite by iron oxides, clay particles, and soil organic matter (SOM) in soils, selenate exhibits higher bioavailability than selenite [3]. The transformation dynamics of these two selenium fertilizers in soil show distinct differences:

- Exogenous application of selenite significantly increases the bioavailability of soil selenium, whereas selenite has a relatively weaker effect.
- After selenate application, selenium primarily exists as SOL-Se (water-soluble form), while selenite application mainly leads to EXC-Se (exchangeable form). Over time, the available selenium (SOL-Se + EXC-Se) gradually transforms into more stable forms.

The higher adsorption capacity of soil components (e.g., metal oxides, clay minerals, and organic matter) for selenite compared to selenite results in lower availability of selenite in soils.

## 5. Effects of soil Ph and Eh on selenium availability

The chemical speciation and bioavailability of selenium in soil are significantly influenced by soil pH. In weakly acidic soils, selenium exhibits low solubility and primarily exists as Se (IV). In contrast, under neutral or alkaline conditions, selenium solubility increases and predominantly occurs as Se (VI). In alkaline environments, lower-valence selenium (e.g., selenite) can be oxidized to higher-valence forms (e.g., selenate), thereby enhancing selenium bioavailability. The bioavailability of selenium increases with rising soil pH due to two key mechanisms. The reduction of $H^+$ concentration leads to increased negative surface charges on soil particles. This creates electrostatic repulsion against negatively charged selenate and selenite ions, promoting their release from soil solid phases into solution. Rao *et al.* investigated selenium speciation characteristics and influencing factors in Wanyuan City, Sichuan Province, finding significant correlations ($p<0.05$) between soil pH and SOL-Se, EXC-Se, and RES-Se fractions. Soil redox potential (Eh) plays a crucial role in selenium bioavailability by governing valence state transformations [4]. Additionally, soil pH indirectly affects selenium speciation through multiple pathways:

- Modulating redox potential (Eh)
- Altering clay mineral adsorption capacity
- Influencing microbial activity

These factors collectively determine the transformation dynamics of selenium species in soil environments.

## 6. Effect of soil organic matter content on selenium availability

Soil organic matter (SOM), as a crucial soil component, exerts complex influences on selenium bioavailability. This complexity manifests in two contrasting mechanisms:

a) **Positive effects:**
   - Increased SOM content elevates organic-bound selenium levels
   - Mineralization of organic-bound selenium releases soluble low-molecular-weight organic selenium compounds.
   - This process enhances selenium bioavailability.

b) **Negative effects:**
   - When selenium binds with macromolecular organic compounds or becomes incorporated into microbial amino acids and proteins
   - SOM demonstrates even stronger selenium fixation capacity than clay minerals.
   - Consequently reduces selenium bioavailability.
   - higher available selenium content in high-SOM soils under low pH conditions, indicating a positive correlation
   - An inverse relationship between SOM and available selenium content
   - SOM, iron-manganese oxides, and clay minerals as primary factors governing selenium speciation in soils.

## 7. The effect of selenium fertilizer types on plant selenium uptake

Both *et al.* conducted a foliar selenium application experiment on maize and found that sodium selenate and sodium selenite were the most effective in increasing selenium content in maize, followed by SeCys2, SeMet, and MeSeCys [5]. Foliar application of both sodium selenate and sodium selenite during the pre-grain filling stage of wheat significantly increased selenium content in wheat grains, with sodium selenate being notably more effective than sodium selenite. The application of sodium selenate and sodium selenite on wheat and found that selenium accumulation in wheat leaves was higher with sodium selenate treatment than with sodium selenite. Numerous studies have indicated that soil application of selenate is more effective than selenite in enhancing selenium uptake in wheat.

## 8. The effect of selenium fertilizer application timing on plant selenium uptake

The ability of plants to absorb and accumulate selenium varies with different growth stages. Zhao *et al.* found that applying selenium fertilizer at the seedling stage significantly increased selenium content in wheat grains compared to basal application, possibly because some of the selenate applied at the basal stage had converted into less available selenite before the rapid growth phase of wheat [6]. Similarly, studies have shown that soil application of selenium during the later growth stages of wheat is more effective than early or sowing-stage application. Malagoli *et al* demonstrated that foliar selenium application during the grain-filling stage resulted in better selenium enrichment effects compared to application at the jointing stage [7]. Wiesner-Reinhold *et al*. suggested that foliar application of selenite during the heading-flowering stage of wheat promoted selenium accumulation and increased yield, with an optimal concentration of 20-30 $mg \cdot L^{-1}$. Additionally, selenium application at the booting stage led to significantly higher selenium content in wheat grains than application at the jointing stage [8].

These findings indicate that the effectiveness of selenium biofortification in wheat varies depending on the application timing, with later growth stages generally yielding better results than early stages. Currently, most studies on selenium application at different wheat growth stages focus on foliar spraying, while research on the effects and mechanisms of soil-applied selenium on selenium uptake, translocation, and accumulation at different growth stages remains relatively limited

## 9. The influence of soil properties on selenium uptake by plants

The absorption of selenium by plants is critically controlled by the available selenium content in the soil. Exogenous selenium is easily adsorbed and immobilized in the soil, so enhancing the selenium uptake capacity of wheat roots is key to improving selenium utilization. The absorption of selenium by wheat roots primarily depends on the bioavailability of selenium in the soil, which is mainly influenced by factors such as selenium speciation, pH, Eh, and soil organic matter (SOM) content. The research on wheat field soils showed that the available selenium content in soil is positively correlated with SOM and cation exchange capacity. Therefore, increasing SOM content in agricultural production can effectively enhance the available selenium content in the soil, thereby improving selenium bioavailability. Existing studies indicate that rhizosphere processes, driven by plant roots and involving plant-soil interactions, are key to limiting nutrient uptake and utilization by plants. Thus, elucidating the rhizosphere processes involved in efficient selenium absorption and utilization by winter wheat, optimizing the coordination between the rhizosphere environment and rhizosphere microorganisms, and fully exploiting the biological potential of selenium uptake in winter wheat will help improve the utilization efficiency of soil selenium by winter wheat.

**10. Funding:** This work was supported by Students Innovation and Entrepreneurship Training Program (KC2024036) and Research of Innovative Prevention and Control Technology of Plant Pests and Diseases Based on the Synergistic Effect of Microbial Fertilizer and Electrolytic Functional Water.

## 11. References

1. Hu T, Li L, Hui GF, et al. Selenium biofortification and its effect on multi-element change in Auricularia auricula. Food Chemistry. 2019;295:206–213.
2. Rao S, Yu T, Cong X, et al. Transcriptome, proteome, and metabolome reveal the mechanism of tolerance to selenate toxicity in Cardamine violifolia. Journal of Hazardous Materials. 2021;406:124283.
3. Wang D, Zhang Y, Chen QL, et al. Selenium-enriched Cardamine violifolia improves growth performance with potential regulation of intestinal health and antioxidant function in weaned pigs. Frontiers in Veterinary Science. 2022;9:964766.
4. Rao S, Yu T, Cong X, et al. Effects of selenate applied at two growth stages on the nutrient quality of Cardamine violifolia. Scientia Horticulturae. 2021;288:110352.
5. Both EB, Shao SX, Xiang JQ, et al. Selenolanthionine is the major water-soluble selenium compound in the selenium tolerant plant Cardamine violifolia. Biochimica et Biophysica Acta (BBA) - General Subjects. 2018;1862(11):2354–2362.
6. Zhao XL, Zhao Q, Chen HB, et al. Distribution and effects of natural selenium in soybean proteins and its protective role in soybean β-conglycinin (7S globulins) under AAPH-induced oxidative stress. Food Chemistry. 2019;272:201–209.
7. Malagoli M, Schiavon M, Dall'Acqua S, et al. Effects of selenium biofortification on crop nutritional quality. Frontiers in Plant Science. 2015;6:280.
8. Wiesner-Reinhold M, Schreiner M, Baldermann S, et al. Mechanisms of selenium enrichment and measurement in brassicaceous vegetables, and their application to human health. Frontiers in Plant Science. 2017;8:1365