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# Role of Selenium in Agriculture and Horticulture: A Review

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***Abstract***

Selenium plays a dual role in agriculture and horticulture: it enhances crop yield and nutritional quality while also acting as a biofortification agent to improve human health. However, its application requires careful management due to narrow margins between deficiency and toxicity.

## 1. Introduction

Selenium (Se) is a trace element vital for human and animal health, but in plants it functions as a beneficial element rather than an essential nutrient. Its agricultural use is primarily focused on biofortification, where selenium-enriched fertilizers or foliar sprays increase selenium concentrations in grains, vegetables, and fruits to address dietary deficiencies in human populations. Research shows that selenium application can enhance crop yield, improve nutritional quality, and strengthen disease resistance, making it a valuable tool in sustainable farming systems (**Dailin *et al.*, 2025**). In cereals such as wheat and rice, selenium fertilization has been widely adopted to improve grain selenium content without negatively affecting yield, thereby supporting public health initiatives in selenium-deficient regions (**Huang et al., 2023**).

In horticultural crops, selenium plays a role in enhancing antioxidant capacity, delaying senescence, and improving stress tolerance. Vegetables like spinach, lettuce, and tomatoes benefit from selenium supplementation through improved shelf life and nutritional enrichment. Selenium also helps mitigate oxidative damage caused by abiotic stresses such as drought, salinity, and heavy metal toxicity, thereby supporting crop resilience under challenging environmental conditions. Additionally, selenium nanoparticles (SeNPs) are being explored for precision horticulture, offering controlled delivery of selenium to plants with minimal environmental impact (Bano et al., 2023). These applications highlight selenium's potential as a multifunctional agent in horticulture, improving both crop performance and consumer health outcomes (**Huang et al., 2023**).

## 2. Mode of action

Selenium enters plants primarily as selenate ($SeO_4^{2-}$) or selenite ($SeO_3^{2-}$), which are absorbed through sulfate transporters due to their chemical similarity to sulfur (Figure 1). Once inside, selenium is metabolized into organic forms such as selenocysteine and selenomethionine, which can be incorporated into proteins. These selenium-containing compounds enhance the activity of antioxidant enzymes like glutathione peroxidase, thereby reducing oxidative stress and protecting cellular structures from damage. Selenium also influences secondary metabolism, stimulating the production of phenolics and flavonoids that strengthen plant defense mechanisms. At optimal concentrations, selenium improves photosynthesis, chlorophyll stability, and stress tolerance against drought, salinity, and heavy metals. However, excessive selenium disrupts protein structure and sulfur metabolism, leading to phytotoxicity and growth inhibition (Deng et al., 2025).

In agricultural crops, selenium is absorbed primarily as selenate ($SeO_4^{2-}$) and selenite ($SeO_3^{2-}$) from soils or foliar sprays. Once inside plant tissues, selenium can substitute for sulfur in amino acids, forming selenocysteine and selenomethionine, which are incorporated into proteins. These compounds enhance antioxidant enzyme activity, particularly glutathione

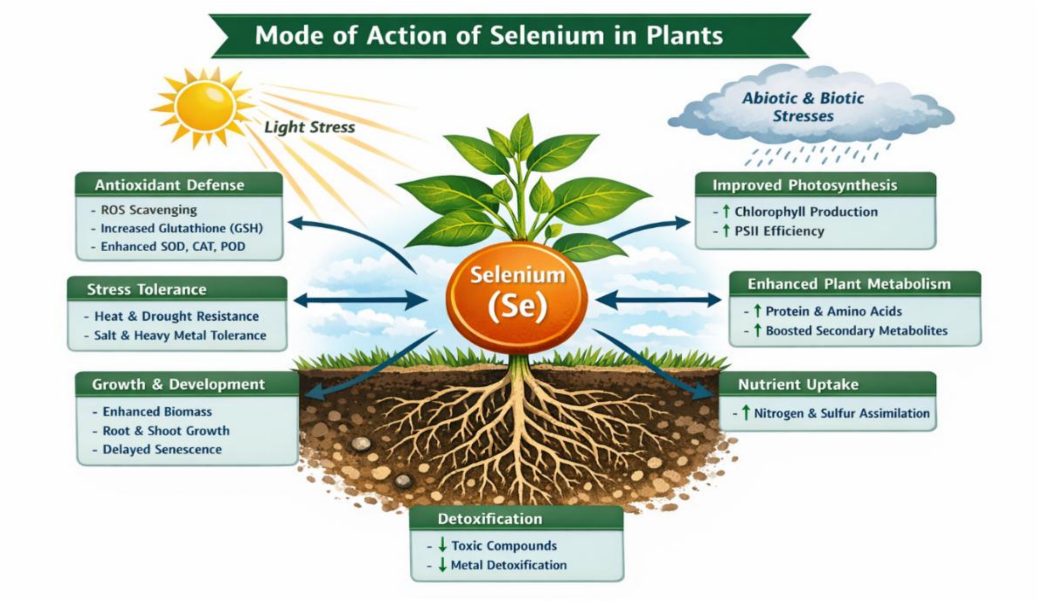


**Figure 1: Mode of action selenium in plants**



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peroxidase, reducing oxidative damage caused by drought, salinity, or heavy metals. Selenium also influences secondary metabolism, stimulating the production of phenolic compounds and flavonoids that strengthen plant defense mechanisms. At low concentrations, selenium promotes photosynthesis and growth, but excessive accumulation disrupts sulfur metabolism and leads to phytotoxicity (Ratnasekera et al., 2025).

In horticultural crops, selenium's role is closely linked to stress mitigation and postharvest quality improvement. By enhancing antioxidant capacity, selenium delays senescence in vegetables and ornamentals, prolonging shelf life and floral longevity. Selenium nanoparticles (SeNPs) are particularly effective, as they provide controlled release and higher bioavailability, improving tolerance to abiotic stresses while minimizing toxicity risks. Studies show that SeNPs enhance chlorophyll content, stabilize membranes, and reduce reactive oxygen species accumulation, thereby maintaining crop vigor under stress conditions. Additionally, selenium fortification enriches edible tissues with bioavailable selenium, contributing to human nutrition through horticultural produce (**Zhou et al., 2025**).

## 3. Applications in Agriculture and Horticulture

Selenium is applied in Indian agriculture mainly as a micronutrient supplement, but recommended dosages are very low (measured in grams per hectare) because excess selenium can be toxic (Tables 1 and 2 and figure 2). Application is usually done as foliar sprays or seed treatments at specific crop growth stages such as vegetative or early reproductive phases.

**Table 1: Crop wise Recommended Selenium Dosage, Stage of Application and Method of Application**

| Crop | Recommended Selenium Dosage | Stage of Application | Method of Application |
|---|---|---|---|
| Wheat | 10–20 g Se/ha | Tillering to boot stage | Foliar spray (sodium selenate/selenite) |
| Rice | 10–15 g Se/ha | Active tillering stage | Foliar spray or seed priming |
| Maize | 15–20 g Se/ha | Vegetative stage (4–6 leaf stage) | Foliar spray |
| Soybean | 10–15 g Se/ha | Early flowering stage | Foliar spray |
| Pulses (Chickpea, Lentil) | 10–12 g Se/ha | Pre-flowering stage | Foliar spray |



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| Vegetables (Tomato, Cabbage, Onion) | 5–10 g Se/ha | Vegetative stage | Foliar spray |
| Oilseeds (Mustard, Sunflower) | 10–15 g Se/ha | Pre-flowering stage | Foliar spray |
| Fruits (Citrus, Grapes) | 5–10 g Se/ha | Vegetative flush or pre-flowering | Foliar spray |

3.1 **Cereals**

Cereals such as wheat, rice, maize, and barley are major dietary staples worldwide, yet they often lack sufficient selenium to meet human nutritional needs. Selenium fertilization—especially through foliar application of selenate—has been shown to significantly increase selenium concentrations in grains, making biofortification a practical strategy to combat "hidden hunger" caused by micronutrient deficiencies. Selenium-enriched cereals contribute to improved human health by supporting antioxidant defense, immune regulation, and detoxification processes. Studies highlight that foliar sprays are more efficient than soil applications, with selenate outperforming selenite in terms of uptake and translocation to edible tissues. Importantly, selenium supplementation does not negatively affect cereal yield, making it a sustainable approach to enhance both crop productivity and nutritional quality (**Borthakur *et al.*,2025**).

**3.2 Vegetables**

In vegetables, selenium is widely used for biofortification, helping to address micronutrient deficiencies in human diets. Foliar sprays or soil supplementation with selenium compounds (selenate or selenite) increase selenium concentrations in leafy greens such as spinach and lettuce, as well as in tomatoes, cucumbers, and onions. This enrichment not only improves the nutritional value of these crops but also enhances their antioxidant capacity, reducing oxidative stress and prolonging postharvest shelf life. Selenium also modulates plant secondary metabolism, stimulating the production of phenolic compounds and flavonoids that strengthen defense mechanisms against abiotic stresses like drought and salinity **Dishri *et al.* 2025**).

**3.3 Floriculture & Ornamentals**

Recent studies highlight selenium's ability to modulate ethylene metabolism, a key hormone regulating flower senescence. By reducing ethylene production and enhancing antioxidant enzyme activity, selenium treatments help maintain floral freshness and extend vase life in cut flowers such as roses, carnations, and chrysanthemums. This selenium–

ethylene interplay has been shown to delay petal wilting, abscission, and bud abortion, thereby improving postharvest longevity and consumer satisfaction. Selenium supplementation also stabilizes chlorophyll and reduces reactive oxygen species accumulation, which contributes to prolonged ornamental quality under stress conditions (Costa et al., 2020).

Beyond traditional cut flowers, selenium has demonstrated benefits in potted ornamentals and floriculture crops, where it enhances stress resistance and delays leaf yellowing. Selenium nanoparticles (SeNPs) are particularly promising, as they provide controlled release and higher bioavailability, improving plant vigor while minimizing toxicity risks. Research indicates that SeNPs stimulate physiological responses such as improved photosynthesis, membrane stability, and secondary metabolite production, all of which contribute to longer-lasting ornamental appeal. These findings suggest that selenium can complement existing postharvest treatments by offering an alternative mechanism to extend floral longevity and marketability in the global floriculture trade (Khan et al., 2023).

### 3.4 Animal Forage Crops

Selenium is an essential trace element for animals, required for antioxidant defense, immune function, and reproductive health. Since many soils worldwide are naturally deficient in selenium, forage crops often lack sufficient levels to meet livestock dietary needs. To address this, selenium fertilization of pastures—through soil application, foliar sprays, or selenium-enriched fertilizers—has been widely adopted. Research shows that selenium-enriched forage improves animal growth, fertility, and disease resistance, while also preventing deficiency-related conditions such as white muscle disease in ruminants. Selenium supplementation in forage crops enhances the activity of selenoproteins like glutathione peroxidase, which protect animals against oxidative stress and improve overall metabolic efficiency. Importantly, selenium biofortification of forage is considered a sustainable strategy, as it delivers selenium naturally through the food chain without requiring synthetic supplementation in animal diets (Javeed et al., 2025).

**Table 2**: **Comparative Benefits of Selenium in Crops**

| Crop/Use | Selenium Effect | Impact |
|---|---|---|
| Cereals (Wheat, Rice) | Biofortification of grains | Human dietary selenium intake |
| Vegetables (Spinach, Tomato) | Stress tolerance, antioxidant boost | Improved yield & shelf life |
| Fruits (Cucumber, Citrus) | Enhanced nutritional quality | Marketability & consumer health |



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| Ornamentals | Delayed senescence | Longer floral display |
| Forage crops | Selenium-enriched fodder | Livestock health improvement |

## 4. Risks and Challenges of Selenium in Agriculture and Horticulture

One of the primary challenges in using selenium for crop improvement is its narrow threshold between beneficial and toxic levels (Figure 2). While low concentrations enhance antioxidant activity and improve plant resilience, excessive selenium can disrupt sulfur metabolism, cause chlorosis, inhibit growth, and lead to phytotoxicity in sensitive crops. This makes dosage optimization critical, especially when applying selenium through soil amendments or foliar sprays. Furthermore, selenium biofortification strategies must balance crop enrichment with food safety, as excessive accumulation in edible tissues can pose health risks to consumers.

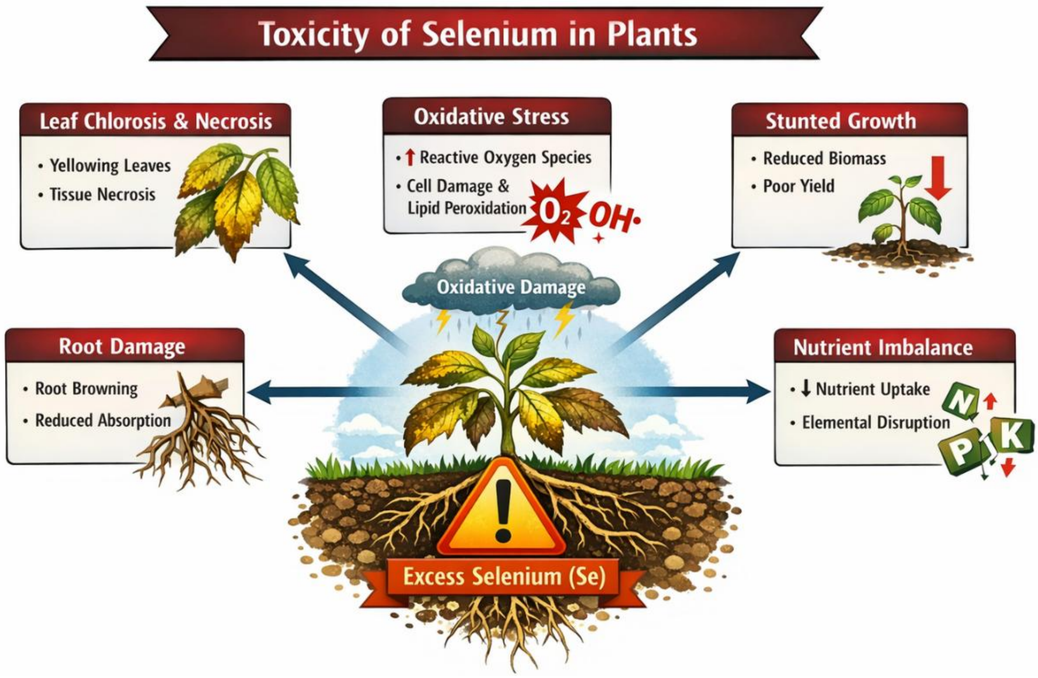


**Figure 2: Toxicity of selenium in plants**

Environmental concerns also pose significant challenges. Selenium is a redox-active element that can leach into groundwater or accumulate in soils, potentially contaminating ecosystems and harming aquatic life. Regions with naturally high selenium levels already face risks of bioaccumulation, and indiscriminate use of selenium fertilizers can exacerbate these problems. Additionally, variability in soil chemistry affects selenium bioavailability, making it difficult to standardize application practices across diverse agroecosystems. Regulatory frameworks emphasize the need for controlled application methods—such as foliar sprays or seed treatments—to reduce environmental impact while ensuring effective biofortification. Despite these challenges, selenium remains a promising tool in sustainable agriculture, provided its use is carefully monitored and integrated into precision farming practices (Dailin *et al.* 2025).

## 5. Conclusion

Selenium is emerging as a biofortification tool in agriculture and horticulture, enhancing crop nutritional quality and resilience. Its applications span cereals, vegetables, fruits, ornamentals, and forage crops. However, precision in dosage and application methods (soil additives, foliar sprays, seed treatments) is critical to maximize benefits while avoiding toxicity. With growing interest in functional foods and sustainable farming, selenium use is likely to expand as part of integrated crop management strategies.

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