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# Applied Selenium Based Nanocomposite for Bio application

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## Abstract

Agricultural productivity is highly challenged by lack of space, diseases and changes in agro climatic conditions. Nanoparticles-reinforced polymer-based materials effectively combine the functional properties of polymers and unique characteristic features of nanoparticles. Biopolymers have attained great attention, with perspective multifunctional and high-performance nanocomposites exhibiting a low environmental impact with unique properties, being abundantly available, renewable, and eco-friendly. SeNPs has attracted increasing attention due to their high bioavailability and novel therapeutic properties. XRD & UV-visible optical absorption spectroscopy techniques have been employed to characterize the as prepared or synthesized selenium bio inorganic nanoparticles. Selenium is trace mineral which are crucial for the maintenance of plant physiology in agriculture science. The particle size was calculated using Scherer's formula for XRD and a equation for UV-vis, finally the lowest particle size of Se nanoparticle was 48 ± 5 nm. Beyond synthesis and characterization, the relevance of SeNPs to agriculture is discussed in the context of nano-enabled stress tolerance (drought/salinity), crop quality, and safer delivery approaches, while emphasizing dose-dependence and environmental risk governance. Recent literature indicates SeNPs can improve crop performance under abiotic stress when applied at optimized concentrations, but also highlights that nano-inputs require risk-aware deployment frameworks, including exposure assessment and regulation-aligned safety evaluation.

**Keywords:** Agriculture, UV vis, soil enhancement, nanotechnology, Se nanoparticles, XRD.

## Introduction

Agriculture is the major source of food and feed for humans and domestic animals. However, agricultural crop pests, climate change events such as drought, and low nutrient use efficiency are significant hindrances to achieving global food security. The efficacy of conventional fertilizer-micronutrient amendments is hindered by low nutrient bioavailability in neutral to alkaline soils and poor basipetal transport in plants. Similarly, the use of conventional pesticides (including insecticides and herbicides) is encumbered with the challenges of excessive use of the chemicals and unintended contamination of the environment. [1] Hence, there is urgent need for sustainable alternative strategies to improve crop production and to manage plant pests and diseases. Numerous publications describe the increase in yield of various plants as a result of better soil conditions. When working in this field, we always deal with water, aqueous media and bio-related systems. Thus, we increasingly walk in a green area becoming greener via replacing the synthetics with the bio-based materials. Hence the major goal of the present day agriculture is to maximize land +and water productivity without threatening the environment and the natural resources.[2,7] Se nanoparticles have a potential antioxidant activity with reduced toxicity due to its redox state of zero ($Se^0$). Selenium nanoparticles are bright red and highly stable colloidal state has been synthesized to be used in nutrition and developed for applications in medical therapy.[8,9] Se nanoparticles showed higher inhibition of ROS which suggests the free radical scavenging efficiency of Se nanomaterial through increment of total antioxidant content reduced risk of Se nanoparticles on living organisms. The biological activity of Se nanomaterial increases with their surface to volume ratio and decreasing particle size. Se nanocomposites as a fertilizer can be used for increasing productivity of crop yield. The effects of Se nanocomposites on total antioxidant values, protein profiles, fatty acids composition in plants and their toxic effects on in cell lines to validate weather yielded seeds originated from Se nanocomposites treated plants possess biosafety properties.[3]

The goal of developing green nanotechnology, which utilizes biological pathways for the synthesis of nanomaterials is minimizing the production of hazardous substances. Meanwhile, the amount of energy input in green nanotechnology is much lower than in other technologies; almost no toxic chemicals are produced during synthesis, and their environmental compatibility is very high.[4] Non-probiotics bacteria Stenotrophomonasacidaminiphila was used for Se nanoparticles biosynthesis. This Se-nanoparticless is than coated with bio-polymer or polysaccharide β-D glucan. β-D-glucan polysaccharides is naturally present in the cell walls of cereals, bacteria, and fungi, with significantly differing physicochemical properties dependent on source.[5,10]

In the future world, demand for agro products will increase tremendously while natural resources such as soil fertility, land, and water are in limited quantity. The production costs inputs like chemical fertilizers and pesticides is expected to increase at an alarming rate due to limited reserves of fuel such as petroleum for poor farmers. In order to overcome these constraints, precision farming is a better option to reduce production costs and to maximize output, i.e. agricultural production. Through advancement in nanotechnology, a number of state-of-the-art techniques are available for the improvement of precision farming practices that will allow precise control at nanometer scale.

Advantage of Se nanocomposites is that they do not leach slowly from the soil and do not dissolve in water or aqueous solutions. There by enhancing soil permeability, reducing compaction tendency, stopping erosion and water run-off. Se nanocomposites may be absorbed by microorganisms in the soil, sediments and plant roots. These Se nanocomposites are then transferred from the roots to other parts of the plants where by stimulating plant growth. Se nanocomposites have a positive effect on the plant system and can improve seed germination leading to enhancement in crop quality and crop yield at low cost in rural areas.

Se nanocomposites can improve crop production by effective pest, microbial, and weed control with high economic value, security, and safety for poor farmers in rural areas. It also plays a key role in food processing, food modification, prolonged shelf life, minimized biomass losses, and provides safe agriculture technology for poor farmers. Nanotechnology also minimizes post-harvest losses with better safety, stability, and packaging quality. Subsequently, sustainable agricultural advancement of poor farmers worldwide can be achieved with the help of nanotechnology to improve resource efficiency, strengthening resilience and securing social equity/responsibility of agriculture and food systems.

**Material and Methods**

The Polyacrylic acid (PAA) was obtained from Merck, India. All the other chemicals used were of GR grade, procured from local market. Selenium powder was purchased from Aldrich. Aqueous solutions were prepared, using water obtained from Millipore-Q water purification system (with conductivity of 0.66 $\mu Scm^{-1}$, or less).

Sodium selenosulphate ($Na_2SeSO_3$) solution was prepared by refluxing a mixture of selenium (2.7g) and $Na_2SO_3$(25g) in 150mL water at 80◦C, for about 12 hours. This sodium selenosulphate ($Na_2SeSO_3$) solution (~0.25 mol $dm^{-3}$), containing unreacted $Na_2SeSO_3$, was used as a stock for Se precursor. An aqueous PAA stock solution, 1% by weight, was prepared by dissolving 1.0 g of PAA in100mL of water, while stirring at 80◦C. The above stocksolutions were diluted to the required concentrations fordifferent experiments. [6,11], PAA-stabilized Se nanoparticles were synthesized byreaction of sodium selenosulphatewith different concentrations of acids organic in aqueous medium, in thepresence of PAA as a stabilizer, in the concentration rangefrom 0.01 to 0.1%. The formation of orange-red-colouredselenium nanoparticle solution was observed in less than one minute.

**Results and Discussion**

The crystalline structure of the selenium nanoparticles was investigated using grazing-angle X-ray diffraction (GAXRD). Samples were analyzed both before and after mild heat treatment. The heat-treated sample, maintained at 90 °C for 2 hours, displayed distinct diffraction peaks corresponding to crystalline selenium (Figure 1). In contrast, the as-prepared, non-heated sample exhibited broad and poorly defined peaks, indicating an amorphous structure. Amorphous selenium is typically associated with a red coloration, which is consistent with the appearance of the colloidal sol immediately after synthesis. Heat treatment promoted atomic rearrangement, leading to partial crystallization and sharper diffraction peaks.

The crystalline structure of the Se nanoparticles was determined by X-Ray diffraction technique. The GAXRD pattern of the as prepared Se nanoparticle sample, after heat treatment at 90◦C, for 2hrs is displayed in Figures 1.

The X-Ray diffraction pattern of the synthesized selenium nanoparticles, without heat treatment, is much more noisy, with broader peaks (plot not shown), indicating amorphous nature of the particles. It is believed that amorphous selenium is red in color, which is further confirmed by selenium sol presented in Figure 1. All the diffraction pattern peaks in Figure 1 correspond to trigonal phase, with lattice constants a =4.292 A° and c = 4.898 A°, which match very well with the reported values (JCPDS file no. 06-362). The particle size was calculated using Scherer’s formula and the lowest particle size of Se nanoparticle was 48 nm.  All observed diffraction peaks in the heat-treated sample matched well with the trigonal phase of selenium, confirming the formation of crystalline Se nanoparticles. The calculated lattice parameters ($a \approx 4.29$ Å and $c \approx 4.90$ Å) were consistent with standard reference data for trigonal selenium. No impurity peaks were detected, suggesting the formation of phase-pure selenium nanostructures.

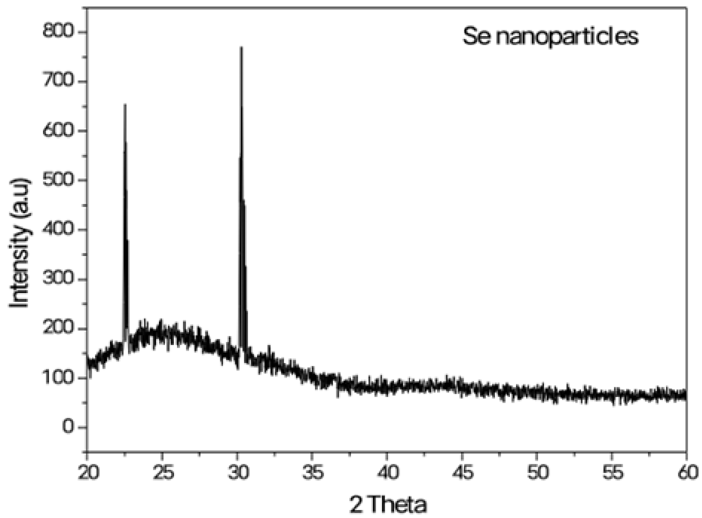


Figure 1: X- Ray Diffraction Pattern of Se Nanoparticles

Figure 2 represents the effect of sodium Selenosulphate and PAA concentrations on UV-visible absorption spectra of the selenium nanoparticle sols synthesized by the reaction of sodium selenosulphate with different conc. of organic acids for agriculture purpose. [6]

UV–Visible absorption spectroscopy was employed to study the optical behavior of the selenium nanoparticle sols (Figure 2). The absorption spectra showed broad bands in the visible region, typical of selenium nanoparticles. The exact position and intensity of these absorption peaks varied depending on the concentrations of sodium selenosulphate and PAA used during synthesis. At higher precursor concentrations, a red shift in the absorption band was observed, indicating the formation of larger nanoparticles due to increased nucleation and growth rates. Conversely, higher PAA concentrations led to a slight blue shift and reduced peak intensity, suggesting better stabilization and formation of smaller, more uniformly dispersed nanoparticles. These spectral variations confirm that both precursor and polymer concentrations play a critical role in controlling particle size and dispersion. The tunability of optical properties highlights the potential of these nanoparticles for applications in sensing, imaging, and agricultural nanotechnology.

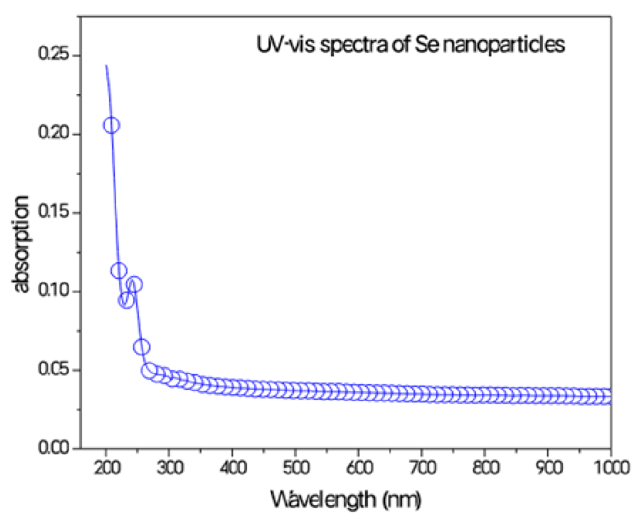


Figure 2: Optical Absorption spectra of as prepared nanoparticles

**Role of PAA as Stabilizer**

Polyacrylic acid served not only as a stabilizer but also as a size-controlling agent. The carboxyl functional groups of PAA interact with the nanoparticle surface through electrostatic attraction and coordination bonding. This interaction forms a protective polymer layer around each particle, preventing agglomeration caused by van der Waals forces. At low PAA concentrations, insufficient surface coverage may allow partial aggregation, resulting in larger particles. At higher concentrations, enhanced steric stabilization limits particle growth, yielding smaller and more stable nanoparticles. This demonstrates that polymer concentration is a key parameter for tailoring nanoparticle characteristics.

**Applications of Selenium Nanotechnology in Agriculture**

Selenium nanotechnology has emerged as a promising tool for sustainable agricultural development, particularly in rural areas where nutrient deficiencies and crop stress are prevalent. Selenium is a trace element that, in small quantities, plays beneficial roles in plant metabolism. When delivered in nanoparticle form, selenium exhibits improved bioavailability and controlled release properties compared to bulk forms.

**Enhancing Crop Yield and Stress Tolerance**

Selenium nanoparticles can improve plant growth by enhancing antioxidant defense systems. They help plants mitigate oxidative stress caused by drought, salinity, and extreme temperatures. By improving chlorophyll synthesis and photosynthetic efficiency, selenium contributes to better crop productivity.

**Micronutrient Delivery**

Nanotechnology enables precise delivery of micronutrients directly to plant tissues. Selenium nanoparticles can act as slow-release fertilizers, ensuring efficient uptake and minimizing nutrient loss through leaching. This approach reduces the quantity of fertilizer required, lowering environmental contamination.

**Disease Resistance**

Selenium nanoparticles exhibit antimicrobial properties that can help protect plants from pathogenic fungi and bacteria. Their small size allows them to penetrate microbial membranes, disrupting metabolic processes and inhibiting pathogen growth.

**Food Quality and Nutrition**

Application of selenium nanofertilizers can increase selenium content in edible plant parts, contributing to biofortification. This is especially important in regions where selenium deficiency in soil leads to poor dietary intake in humans.

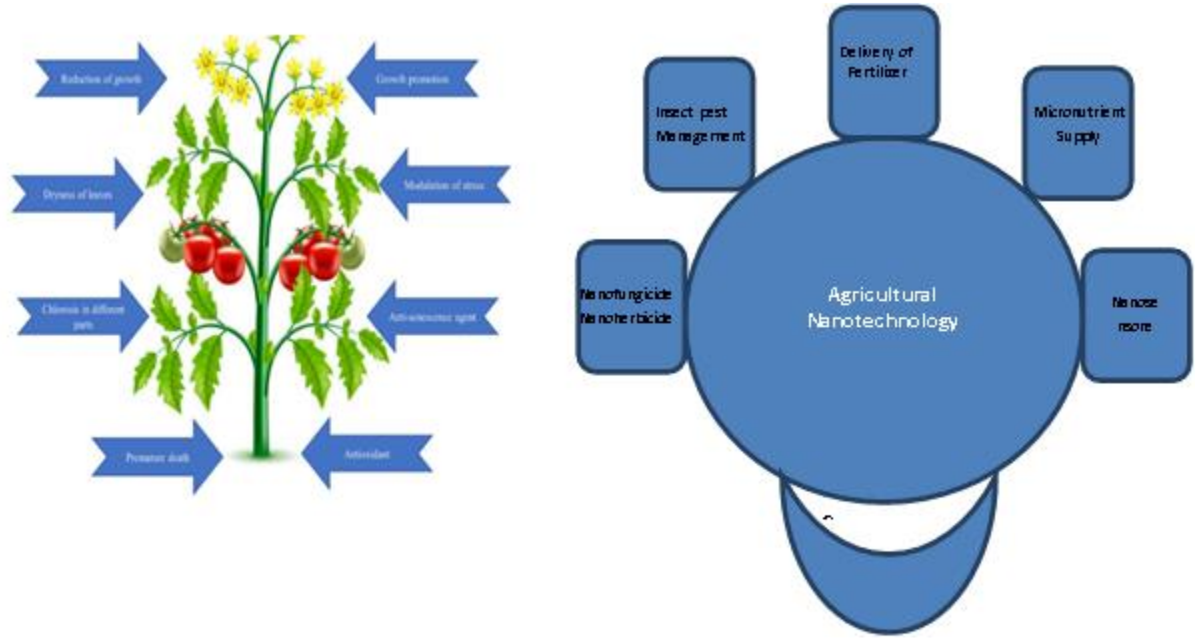


Figure 3: Schematic diagrams of applications of Se nanotechnology in agriculture for production Increase in rural area.

**Challenges and Safety Considerations**

Despite promising benefits, the large-scale application of nanotechnology in agriculture requires careful evaluation of environmental and health risks. Nanoparticles may accumulate in soil and water systems, potentially affecting non-target organisms. Long-term toxicity studies and regulatory frameworks are therefore essential. Responsible development involves collaboration among researchers, policymakers, and industry stakeholders. Risk assessment, safe handling guidelines, and eco-friendly synthesis methods must be prioritized to ensure sustainable growth of agro-nanotechnology . The Se- based nanotechnology can productively be used to produce consumer goods for pharma, food, agriculture, construction, and remediation sectors which are advantages in their characteristics. Regarding the future of nanotechnology, we need to focus on assessment and management of risks associated for its promising market growth. Future application of nanotechnology facilitates food preservation, nutrition enhancement, and safe delivery of micronutrients and bioactive components into plants. Se nanocomposites area has established itself as a key enabling technology for a wide range of applications, thus becoming a top priority for science and technology policy development, being already used in hundreds of fertilizer products among the agro industrial sector, healthcare, chemical, composites and energy. Despite the development in Agro-nanotech area, there are some obstacles to a greater impact of nanotechnology in industry. This article intends to briefly the agro products being developed within the consortium, given with them examples of practical applications, security issues and market challenges in order to an effective collaboration between the govt agencies, agriculture scientists and the industrial sector.

**Conclusion**

The Polyacrylic acid-induced synthesis of Se-nanoparticles has been found to be a simple and convenient method, which can be carried out under ambient conditions. PAA was used as a stabilizer or capping agent for the selenium nanoparticles. The size of the selenium particles was found to increase with sodium seleno sulphate concentration. Nanocrystalline nature of the synthesized se nanocomposites particles increase in their processing were confirmed by both

UV-vis and XRD experiments. Nanotechnology consider a novel key to growing agricultural production through implementing nutrient efficiency, improve plant protection practices, also, nanotechnology may have real solutions for various agriculture problems of farmers in rural areas. Selenium at low concentrations has a beneficial influence on plant development and yield. Selenium may work as an essential factor by interfering with several of physiological processes.[12] The present study demonstrates a simple, cost-effective, and environmentally friendly method for synthesizing selenium nanoparticles using polyacrylic acid as a stabilizing agent. The synthesis can be performed under mild conditions, making it suitable for large-scale production. Structural analysis confirmed the formation of trigonal crystalline selenium nanoparticles after mild heat treatment, with an average size of approximately 48 nm. Optical studies revealed that particle size and dispersion could be effectively controlled by adjusting precursor and polymer concentrations. Beyond their physicochemical properties, selenium nanoparticles hold significant promise for agricultural applications. They can enhance plant growth, improve nutrient efficiency, and contribute to crop biofortification. However, balanced implementation with proper safety assessments is essential to maximize benefits while minimizing environmental risks.

Overall, polyacrylic acid-mediated selenium nanoparticle synthesis represents an important step toward integrating nanotechnology into sustainable agricultural practices and rural development strategies.

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