Chapter 16
Agricultural Applications of Chalcogenide-Based Materials:
Toward Sustainable, Smart, and Nutrient-Efficient Farming

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ABSTRACT

Food chain has been altered through farming nanotechnology, which energizes such elements as Sulfur (S) and Selenium (Se), and several industries, such as crop

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farming, aquaculture, tree forestry, animal and poultry farms, and plant nutrients, have utilized this technology. Sulphur nanofertilizers reduce the stress level on the environment, increase the fertility of the soil, and optimize nutrient release. Selenium agents impede the occurrence of micronutrient insufficiency in human beings and animals, and Chalcogenide concentration minimizes the intake of synthetic additives and optimizes the conversion rate of feeds. The use of sulfur fertilizer helps activate sprouting and improves tolerance to diseases. Intelligent sensors with chalcogenides and optoelectronic agricultural plans can provide real-time information on the moisture of the soil, soil nutrients, and stress. These products increase nutrition, demand fewer resources, and provide adaptable agriculture approaches in an evolving climate.

INTRODUCTION

Agriculture, which is the source of food security in the world, encounters a myriad of problems in the 21st century, such as the growing demand for food, the fall in arable land, nutrient loss, climate change, and the rapid increase in population, (Tari et al., 2024). Such problems create the need to move towards more sustainable, efficient, and technologically integrated agriculture. In material science, new materials, particularly nanotechnology and the development of new functional materials, offer promising solutions to the enhancement of the conventional methods of agriculture (Sivasamy et al., 2024). Chalcogenide-based compounds have become one of the suggested materials based on their distinctive physical, chemical, and biological characteristics as a result of group 16 elements [e.g., Sulfur (S), Selenium (Si), and Tellurium (Te)]. The use of chalcogenide compounds in agriculture is a relatively new concept, and use in photonics, energy storage, and electronics is a long-established field. Some of the properties of these materials include tunable bandgaps, photoconductivity, high surface activity, and biological reaction. They interact with soil, water, and plant systems, which makes them the best in designing smart fertilizers, soil conditioners, and sensors. With these capabilities, materials based on chalcogenide can be used to facilitate a new generation of agricultural technologies that will not only be more nutrient-efficient and less toxic to the environment but also be less harmful to the environment and produce more food without disrupting the ecosystem balance, (Sajitha et al., 2024, Tari. et al. 2022).

The contribution of material science in the agricultural sector is also on the increase at a very high rate, involving the use of nanoscale material and smart delivery devices, (Gupta et al. 2024; Tari et al., 2025). Conventional fertilizers and pesticides usually lead to poor utilization, leaching, and pollution of the environment, (Özşirvan et al., 2024; Tari & Patil, 2017a; Yalçın et al. 2023; Tari V& Patil, 2017b). Conversely,

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