


# Chapter 11

## Unveiling Nanomaterial-Induced Toxicity: Navigating Challenges to Modern Cultivation and Soil Management Practices

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### **ABSTRACT**

*In the current landscape, addressing the nutritional needs of our rapidly expanding global populace is imperative. Traditional farming methods face challenges, with approximately one-third of crops succumbing to pests, diseases, natural calamities, soil degradation, and nutrient deficiencies. Nanotechnology have been made in harnessing nanoparticulate systems to enhance quality, act as sensors, combat pests, and bolster fertilisation efforts. Nanotechnology has emerged as a crucial ally in boosting agricultural sustainability by amplifying crop yields and revitalising soil health. Over the past decade, nanotechnology has permeated various sectors, prominently in agro-industrial realms. A profound comprehension of plant-nanomaterial interactions unveils promising avenues for fortifying farming practices, fostering disease resilience, augmenting yields, and optimising nutrient absorption.*

### **INTRODUCTION**

Agriculture is a significant industry involved in producing and supplying various specialized crops for feeding, food, and decorative purposes. It is currently a global industry worth trillions of dollars. To address poverty and hunger caused by limited resources and a rapidly growing human population expected to reach 9.6 billion by 2050, it is crucial to develop highly efficient agricultural technology (Rajput et al., 2021). According to UN projections, the world's population will approach 10.9 billion by the year 2100, leading to an estimated 50% increase in global food demand (Singh et al., 2023a). The contemporary agricultural practices heavily consume resources, making it increasingly unlikely for both modern and traditional agriculture to sustainably meet global needs entirely. Embracing eco-friendly agricultural techniques that enhance productivity, reduce land conversion, employ efficient irrigation methods, and minimize synthetic pesticide usage emerge as pivotal elements in fostering agricultural sustainability (Kah et al., 2018). While chemical fertilizers provide essential nutrients for plant growth and yield optimization, the current agricultural methodologies can only cater to escalating food demands through substantial reliance on fertilizers (X. Zhang et al., 2015). However, the widespread utilization of conventional fertilizers over an extended period has led to significant environmental challenges worldwide, including air pollution, water eutrophication, groundwater contamination, and soil degradation (Ghazaryan et al., 2023).

Today's agricultural practices heavily utilize resources, making it unlikely that traditional methods alone can meet global needs sustainably. Sustainable agriculture hinges on adopting eco-friendly practices like enhancing output, reducing land conversion, employing efficient irrigation, and minimizing synthetic pesticide use (Kah et al., 2018; Singh et al., 2023b). While chemical fertilizers boost plant growth and productivity, current farming methods need heavy fertilizer reliance to meet rising food demands (Zhang et al., 2015). Widespread use of conventional fertilizers has led to environmental issues like air and water pollution, groundwater contamination, and soil degradation (Congreves & Van Eerd, 2015).

To achieve sustainable agriculture, global practices must significantly shift towards embracing scientific and technological advancements. Nanotechnology presents a promising avenue, particularly in developing various types of fertilizers to increase horticultural production while ensuring sustainability significantly (Tolaymat et al., 2015). Nanotechnology, the manipulation of materials at an incredibly small scale (1-100 nanometres), is revolutionizing fields like electronics, medicine, energy, and even agriculture (Boisseau & Loubaton, 2011; Rashidi & Khosravi-Darani, 2011; Yang et al., 2017; Singh et

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