Chapter 19
Utilizing Nanotechnology in Agriculture:
A Balancing Approach Between Environmental Health and Risks

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ABSTRACT

The forthcoming decade is poised to present myriad challenges across various spheres of life. Adverse meteorological and environmental conditions affecting agricultural output will escalate the demand for

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enhanced supplies. Additionally, the burgeoning need for superior quality industrial products, including smart automobiles, among other factors, poses significant hurdles. In recent years, nanotechnology has garnered considerable attention due to its recognized potential across critical sectors such as medicine, pharmaceuticals, plant science research, catalysis, energy, and materials. Nanoparticles (NPs), characterized by their minute size and expansive surface area (ranging from 1 to 100 nanometers), boast a plethora of fascinating applications. These remarkable properties find application in sustainable agriculture through the production of nano-enhanced products like insecticides, pesticides, and fertilizers.

INTRODUCTION

The global population currently stands at approximately 6 billion, with a significant portion residing in burgeoning economies, notably across Asia, constituting roughly 50% of the total populace. Within these regions, a substantial segment grapples with persistent food insecurity, a consequence of environmental challenges or political instability. Conversely, in more developed nations, the focus lies on cultivating crops fortified against pests and drought, thereby bolstering agricultural productivity and output (Singh et al., 2019). On December 29, 1959, at the California Institute of Technology, during the annual meeting of the American Physical Society, Richard Feynman delivered a seminal address titled "There's Plenty of Room at the Bottom," which marked a significant leap towards pioneering a new frontier in physics (Garcia and Garcia, 2018). In his speech, Feynman advocated for the manipulation of matter at the atomic scale, laying the groundwork for the emergence of nanotechnology (NT) research and innovation. This visionary concept has since spurred substantial investment and development, exemplified by initiatives such as the United States National Nanotechnology Initiative (NNI), which proposed a budget of $27 billion for 2019. Notable advancements include the infusion of $10 million by Saudi Aramco Energy Ventures (SAEV) into "Nano-Mech," a prominent producer of nanoproducts, and a substantial $350 million grant to the Massachusetts Institute of Technology for the establishment of the state-of-the-art nanoscale facility known as "MIT nano." Urgent transformations in traditional agricultural practices are imperative to align with the UN's ambitious "Zero Hunger" objective, a pivotal target within the sustainable development goals to be achieved by 2030. Leveraging the advancements in NT holds the key to realizing such enhancements in agricultural productivity and sustainability(Rajput et al., 2021).

In recent decades, scholars have developed a myriad of strategies aimed at modernizing traditional agricultural methods. Notably, among these advancements is the introduction of Nanotechnology (NT), a cutting-edge approach designed to enhance crop productivity by addressing challenges such as plant nutrition optimization, efficient water usage, and safeguarding crops against pests and diseases through the application of nano-enabled formulations. Additionally, precision farming techniques and environmental rehabilitation efforts, facilitated by nano-bioremediation, further underscore the versatility and potential of NT in revitalizing agricultural practices (Kumari et al., 2021). Nanoparticles (NPs), owing to their distinctive physiochemical properties, offer significant advantages across a spectrum of industries, ranging from agriculture to pharmaceuticals, chemicals, biomedicine, optics, textiles, and food production. This widespread adoption underscores the broad applicability and growing significance of NPs in diverse sectors(Shende et al., 2021).

In developing countries, agriculture serves as the cornerstone of their economies. Research in agriculture traditionally revolves around improving crop yield and output, food manufacturing, ensuring food safety, and addressing the ecological impacts of food production, distribution, and storage. Nanomaterials