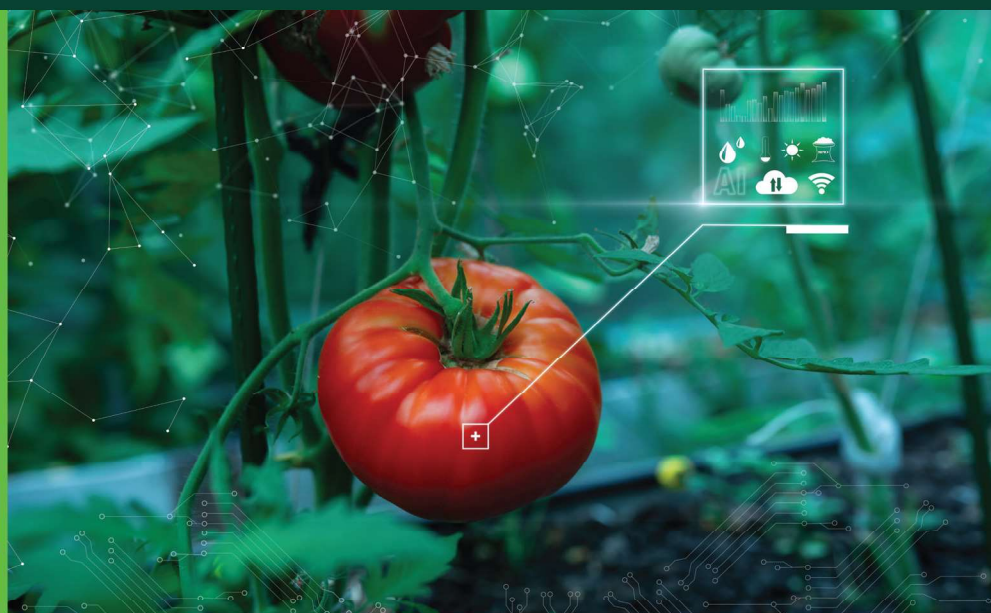


Plant Biology, Sustainability, and Climate Change

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NANOSCIENCE AND NANO-FORMULATIONS FOR SUSTAINABLE VEGETABLE CROP PRODUCTION



Edited by
Azamal Husen



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Fullerene and carbon nanotubes for vegetable seed priming, germination, and seedling development

Megha Barot^a, Jamal Akhtar Ansari^b, Pankaj Sharma^{c,d} and Azamal Husen^{e,f}

^a Research and Development Cell & Department of Environmental Science, Parul Institute of Applied Sciences, Parul University, Vadodara, Gujarat, India, ^b Department of Chemistry, Integral University, Lucknow, Uttar Pradesh, India, ^c Department of Microbiology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India, ^d Department of Ophthalmology & Visual Sciences, University of Illinois Chicago, Chicago, IL, United States, ^e Wolaita Sodo University, Wolaita Sodo, South Ethiopia Regional State, Ethiopia, ^f Department of Biotechnology, Graphic Era (Deemed to be University), Dehradun, Uttarakhand, India

3.1 Introduction

Seed germination represents a pivotal stage in the plant life cycle, directly affecting crop yield, uniformity, and resilience to environmental stressors. For vegetable crops, namely tomato, lettuce, cucumber, and spinach, achieving uniform germination and vigorous seedling development is essential to ensure marketable quality and consistent harvesting. Traditional seed priming methods, viz., hydropriming, osmopriming, and hormonal priming, have proven effective in enhancing germination; however, their benefits appear to have reached a plateau (Farooq et al., 2019; Waqas et al., 2019). This limitation has driven the exploration of innovative technologies like nanotechnology, which presents new opportunities to address enduring agricultural challenges. Among the various nanomaterials (NMs) under investigation, carbon-based nano-particles (NPs), particularly fullerenes and carbon nanotubes (CNTs), have shown promising effects on seed performance. Their capability to penetrate seed coats, interact with intracellular structures, and regulate gene expression positions them as powerful tools in modern seed priming strategies (Husen and Siddiqi, 2014a; Husen, 2020; Fonseca et al., 2024; Chaachouay et al., 2025). Nanotechnology involves the manipulation of materials at the atomic or molecular level, typically within the 1–100 nm range. In plant science, its applications include nano-fertilizers, nano-pesticides, growth stimulants, and seed coatings (Husen, 2022, 2023). Owing to their high surface-area-to-volume ratio, increased reactivity, and ability to cross biological membranes, NPss are particularly effective in interacting with plant systems (Husen and Siddiqi, 2014b). Fullerene (C₆₀), referred to as “buckyballs,” is a

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