

Chapter 2

Nanotechnology and Soil Health: Current Updates and Future Perspective

Seweta Srivastava

*School of Agriculture, Lovely Professional
University, India*

Chandra Mohan Mehta

*School of Agriculture, Lovely Professional
University, India*


Meenakshi Rana

*School of Agriculture, Lovely Professional
University, India*


Diptanu Banik

*School of Agriculture, Lovely Professional
University, India*

Vishnu D. Rajput

 <https://orcid.org/0000-0002-6802-4805>
*Southern Federal University,
Rostov-on-Don, Russia*

Elizaveta Konstantinova

 <https://orcid.org/0000-0002-9836-8721>
Southern Federal University, Russia

ABSTRACT

The soil microbiome in particular is essential for preserving plant health and biomass production. The management of soil microbial communities, whether targeted or inadvertently, appears to have potential for improving food crop yield, quality, and sustainability in the long run. With the development of innovative nano-tools for quick disease diagnosis and improved plant nutrient uptake, nanotechnology holds promise for advancing the agricultural and food industries. Utilizing nano-materials in agriculture offers a special chance to maintain soil health and increase crop yield. The use of nanotechnology in agriculture holds great promise for specific applications such as the development of nano-pesticides and fertilizers that can boost productivity without contaminating soils and offer protection against microbial diseases and insect pests. This chapter provides the current updates along with the sustainability issues, climate change food security and also the future prospects of nanotechnology in soil health management and crop production.

1. INTRODUCTION

Soil is a vital component of the biotic ecosystem that sustains plants as well as animals and engages in a range of processes which can help them to cope up with the changing environmental conditions (Mehta et al. 2022). Long-term food security depends on fertile soils (Rajput et al. 2022). Future growth in the likelihood of unfavourable agroclimatic circumstances will undoubtedly result in an upsurge in biotic and abiotic stressors, that are going to have a significant impact on soil health and crop production (Strer et al. 2018; Raza et al. 2019). The agriculture sector is currently facing significant challenges such as enhancing soil productivity, promoting soil fertility and enrichment, encouraging crop tolerance and adaptability, and utilizing agrochemicals effectively (Maiti and Satya 2014).

In context with this, the implementation of nanotechnology in agricultural field has grown popularity recently (Prasad et al. 2017). With the use of nanotechnology, new products can be developed by altering the physical and chemical characteristics of substances at their molecular level. Research in nanotechnology has exploded in the last few years (Figure 1). It is having an effect on our daily lives and making a lasting impression on our society (Surendranath and Mohanan 2020). It is widely used across every industrial sector, including food, medicine, cosmetics, electronics, pharmaceuticals, and agricultural production, which includes managing soil health (Pramanik et al. 2020; Angelopoulou et al. 2022; Mazayen et al. 2022). According to reports, nanomaterials (NMs) in soil pose an immediate impact on the efficiency of soil microorganisms. Consequently, if the application process is optimized, NMs may enhance the physiological and chemical properties of the soil and consequently foster plant growth (Rajput et al. 2021; Kalwani et al. 2022; Khan et al. 2022).

The use of nanotechnology improved the soil fertility and nutrient uptake by stimulating soil enzymes (Zhao et al. 2021). Degradation of soil nanotechnology also controls the process through which one or more of the soil's potential ecological functions are damaged or eliminated. (Sahana et al. 2022). The interaction of NMs with rhizospheric microbes can enhance both soil health as well as growth of plants (Khan et al. 2022; Manda et al. 2023). A few factors contributing to the NMs' predominance in the rhizospheric region are the use of industrial coated NMs-based products, such as nano-fertilizers (Verma et al. 2022), which demonstrated a favourable effect on the community of soil microbes (Chaudhary et al. 2021). These factors also include changes in plant growth, yield, and quality. However, an overview revealed that the addition of NMs to the soil ecosystem alters the rhizosphere's productivity and the composition of the soil (Rajput et al. 2018; Khanna et al. 2021). Additionally, it was reported that the nature and concentration of NMs, the types of microbial species that occupy the soil, and the soil conditions all affect the net influence of NMs on the soil microbiome (Tian et al. 2019). Accordingly, the utilisation of NMs may benefit soil microorganisms and plants alike, but only if they are used in a carefully monitored manner that considers the kinds, sizes, and length of exposure along with the recommended application dose (Pérez-de-Luque 2017). The scientific community has recently focused a lot of attention on regulating soil microorganisms in order to preserve the soil and mitigate detrimental environmental pressures and factors that affect plant growth. According to numerous scientific studies, soil microorganisms are essential to plant health despite in stressful situations (Jacoby et al. 2017; Fan et al. 2022; Yu et al. 2022). In light of this, the current review focused on nano-inventions that enhance soil wellness by enhancing soil microbiome, future prospects and environmental consequences are also covered.

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