Plant Nano Biology 11 (2025) 100143

Contents lists available at ScienceDirect

Plant Nano Biology

journal homepage: www.journals.elsevier.com/plant-nano-biology

Green synthesis of nanomaterials used as nano-fertilizer for sustainability in crop production: A overview on recent advancements and future perspectives

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ARTICLE INFO

Keywords:
Nanofertilizer
Green synthesis
Sustainable agriculture
Nanoparticles
Characterizations

ABSTRACT

Nano-fertilizers (NFs) have attracted a growing interest in the field of green farming. Materials ranging from 1 to 100 nm provide nutrients to different types of plants. NFs have been recognized as cost-effective alternatives for traditional chemical fertilizers to boost the global food supply in an environmentally friendly manner. These NFs constitutes macronutrients and micronutrients that work as carriers for different type of nutrients, and reduce the additional amount of chemical in plants. However, nano-coated materials with the size more than 10 nm manage to enter through the different parts of plants such as stomata, foliar and roots etc. Green synthesized materials-based NFs effect on productivity of different crops plants. For instance, ZnO based nanoparticles (NPs) NFs effect the productions of the crops such as cucumber, peanuts, cabbage and cauliflower. Rare earth oxides nanoparticles-based NFs effect the productions of various vegetables. Iron oxide along with calcium carbonate nanoparticles-based NFs effect the growth of cereals plant. Significantly, green synthesis of Zinc and copper with the extract of basil plant attributes as significant nano-fertilizers. This review research discusses the potential benefits of nanofertilizers in a variety of areas, including agriculture, production, the mechanism of entrance of nanofertilizers into plants, the process of action, and the impacts of nanomaterials in soil. Policymakers have established standard for regulating the dosage, frequency, and time duration of NF's possible usage in food production.

1. Introduction

Nanotechnology, a multidisciplinary and promising research area, presents numerous possibilities in sectors such as medicine, pharmaceuticals, electronics, and agriculture, offering a wide range of opportunities (Avila-Quezada et al., 2022). Nanoparticles have remarkable and extraordinary characteristics because of their higher reactivity, which is a result of their smaller sizes and large surface areas (Daniel et al., 2004). In recent times, the agriculture research sector is exploring a wide range of nanotechnology applications, focusing on academic and industrial levels for the development of agricultural practices. There are number of challenges faced by farmers in traditional agriculture including chemical toxicity caused by excessive use of fungicides/-pesticides, their high cost, which is out of reach for marginal farmers, especially in developing countries (Avila-Quezada et al., 2022). Plants requires carbon dioxide (CO_2), sunlight, water and a variety of chemical elements to grow and develop. Chemical elements are those elements that the plant can obtain from the soil via roots or aerial parts (Marschner, 1995). Mineral nutrients are those obtained from the soil. Oxygen, hydrogen, and carbon are obtained from water (H_2O) and carbon dioxide (CO_2) are not considered as mineral nutrients. The amount of minerals in the soil varies and is dependent on many factors like microbial activities, cation exchange capacity, quantity of organic matter, soil moisture, pH, redox potential and soil depth etc (Marschner, 1995). In recent times, despite advancements in our knowledge of the mechanisms of plants nutrients uptake, there are currently no conventional fertilizers that effectively supply the ideal amount of nutrients for plants (Adnan et al.,2020). The essential nutrients required for crop

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https://doi.org/10.1016/j.plana.2025.100143
Received 9 May 2024; Received in revised form 20 December 2024; Accepted 30 January 2025
Available online 8 February 2025