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Review Article

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Nano-Fertilizers - A Cutting Edge Approach for Sustainable Agriculture

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Abstract
Nanostructured fertilizers or nano-fertilizers are in the form of nanocarriers, nanocapsules or nanonutrients that should be considered as smart fertilizers that can improve plant nutrient utilization efficiency, control nutrient release and reduce environmental impact. However, there is an urgent need to standardize and evaluate the toxicity of nanomaterials used in the synthesis of nano-fertilizers. Therefore, detailed agricultural field and greenhouse surveys are highly recommended for performance evaluation of nano-fertilizers.

Keywords: Encapsulation, Agro-Industrial Waste, Plasma Vapor Deposition, Chitosan, Sustainability

Introduction

Nano-fertilizers refers to a product in nanometer dynasty that provides nutrients to crops [1]. For example, encapsulation inside nano materials covered with a thin protective polymer film or in the form of particles or emulsions of nano scale dimensions [2, 3].

In the past two decades, numerous difficulties encountered in agriculture have become recurrent. Not due to the lack of space or even investment in technology, but due to regular climatic instabilities caused by worsening of global warming and intense deforestation [4, 5]. Based on this, the precepts of sustainable agriculture have become significant in agricultural research groups, such as the development of green nanomaterials, optimization of agricultural processes, breeding, rational use of pesticides, and others. Efforts by researchers around the world have been growing in the search for smart and greener solutions that can meet global food demands, due to accelerated population growth [6-9]. Given this scenario, special attention is given to biodegradable materials, produced via clean and safe processes [10]. Currently, a worldwide trend has been adopted in the manufacture of nanomaterials by utilizing green processes, thus minimizing the use of toxic reagents, or reusing agro-industrial waste [11]. An important class of agrochemicals impacted by these precepts are the synthesis of nano-fertilizers [12].

There are several ways to obtain nano-fertilizers, such as step-by-step fertilizers and organic fertilizers [13]. The top-down manufacturing process uses large particle-to-nanometer physics techniques [14]. Techniques based on this concept have limitations such as irregularity and particle size control [15]. Another method of producing nano-fertilizers is a bottom-up method based on chemical reactions [16]. The method allows better control over the size of the nanostructures and reduces impurities [17]. Another way to produce nano-fertilizers is the organic method by utilizing microorganisms such as bacteria and fungi [18]. The advantage of obtaining nano-fertilizers through microbes is the low cytotoxicity of the final nano-product [19]. Thus, these various methods employed for the fabrication of nano-fertilizers faces numerous challenges such as energy cost, process performance, and product yield [20].

Nano-Fertilizer Composition

Nano-fertilizers consists of organic or inorganic compounds [21]. Metal oxides such as zinc oxide (ZnO), magnesium oxide (MgO) and silver oxide (AgO) are mainly used for the growth of nanomineral structures [22, 23]. For nanomaterials derived from organic compounds such as polymers, carbon etc, the effectiveness of these nano-fertilizers for example chitosan matrices doped with copper and salicylic acid have been reported in corn products [24, 25]. In addition, increased antioxidant enzyme activity, decreased amount of malondialdehyde and increased concentration of leaf chlorophyll was observed in corn [26].

Mechanisms of Nano-Fertilizer Uptake by Plants

There are several possible mechanisms by which plants absorbs the nutrients released from the applied nano-fertilizers, either through its roots, leaves, or by means of endocytosis [27]. Due to the size of pores and the absorbent factor, absorption by plants roots can severely limit the nutrients that can accumulate in the soil during cultivation [28]. Studies have been reported that the uptake mechanism of nano-fertilizer mediated nutrient release through plant roots is more efficient [29].

Nano-Fertilizer Synthesis

Recent studies have shown that nano-fertilizers are obtained using conventional fertilizers, bulk materials from different parts of the plant, or employing various chemical, physical, mechanical and biological methods [30]. Plant reproduction and productivity have been improved by using nano-fertilizers fabricated either by top-down approach (i.e., splitting a bulk solid into smaller pieces by an external force) [31] or a bottom-up process (by assembling and accumulating atoms or molecules) [32].

Physical Method

Nano-fertilizers can be immobilized or encapsulated with synthetic polymer or nutrients can be coated with thin NP films by employing physical methods such as radiation, mechanical or ultrasonic pressure, thermal or electrical energy [33-35]. These physical methods are based on top-down strategies and are cost-effective, less time and energy consumption, solvent-free, and produce similar NP products with constant dispersion [36]. However, the large amount of waste generated by these facilities makes these physical methods less economical [37].

Chemical Method

On the other hand, chemical methods such as sol-gel method, hydrothermal synthesis, micro-emulsion technique, polymer synthesis, chemical vapor synthesis, plasma vapor deposition technique are the most common methods for nano-fertilizer synthesis [38, 39]. However, the use of reducing and stabilizing agents in the synthesis process affects nano-fertilizer toxicity [40].

Biological Method

Auxiliary biological methods, are economical, less toxic and environmentally friendly [41]. These processes have been documented for the use of biological systems such as bacteria, fungi, yeast, actinomycetes, and plant extracts [42]. These biological methods can be broadly divided into the following:

1. Synthesis using microorganisms
2. Synthesis using biomolecules
3. Synthesis using plant extracts [43].

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Advantages of Nano-Fertilizers

New technologies are constantly being developed, especially in the era of modern agriculture. Environmental issues are a major factor because of the scarcity of natural resources and the amplification of climate impacts from human erosion [44]. Efforts to stimulate agricultural yield for the increasing population, use of nano-fertilizers can be adapted to sustainability, especially for global food production [45]. The following advantages of nano-fertilizers are as follows:

- Possibility to act as a great nutrient release mechanism
- Reducing nutrient loss to the environment [46]
- Numerous synthesis approaches [47]

The following disadvantages of nano-fertilizers are as follows:

- Need for life cycle studies
- Food security
- Lack of long-term environmental studies [48]

Nano-Fertilizers as an Alternative to the Traditional Mineral Fertilizers

Recent studies have shown that excessive use of mineral fertilizers as a source of nitrogen or phosphorus significantly affects the residual mineral mix in the soil and/or its proportion in the air and have negative impact on crop stability and productivity [49]. Therefore, nano-fertilizers could be used as an environmentally friendly alternative to mineral fertilizers as it enhances soil fertility, increases product yield, reduces pollution and also increases microbial activity [50]. Because of the small size of nanoparticles, they serve as vectors of biological factors that binds and penetrates into the plant surface to provide a favorable environment for long-term survival and activation [51]. For example, Titanium oxide (TiO_2) NPs, Silica NPs and Chitosan nanoparticles (CsNPs) [52].

Conclusion

Thus nano-fertilizers can be an effective solution in a variety of agricultural fields as it is employed as a mean to enhance global food production as well as minimizing the release of toxic contaminants in to the environment by incorporating green synthesis methods.

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