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Nano-biofertilizers for Agricultural Sustainability

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Agriculture plays an important role in the world economy, and is known as the backbone of many developing and developed countries. The widespread and continuous use of chemical fertilizers in agricultural systems to increase yields has many health hazards and environmental problems. As a result, a different system needs to be created to improve agricultural productivity and environmental sustainability. Implementing and developing nano-technological advances seems to be a viable option. The utilization of the nano-materials with living organisms such as the nano-biofertilizers (NBFs) is one of the best solutions of agricultural challenges. NBFs transfer nutrients to the plants in an intelligent way, demonstrating their superiority over bulky chemical fertilizers in terms of crop output and environmental sustainability. NBFs help the plants to withstand biotic and abiotic stressors in a better way. Depending on the applications method and particle properties, plants can absorb nano-biofertilizers through their roots or leaves. The nano-biofertlizers could be used to reduce chemical fertilizers for agricultural and environmental sustainability.

Nano-biofertilizers have numerous advantages and provide fresh perspectives on promoting sustainable agriculture and reducing climate change. Nano-fertilizers (NFs) are nano-particles (NPs) delivered to crops in a regulated, intelligent manner and contain both macro- and micronutrients (Figure 1). Nano-fertilizers considered as an outstanding and promising alternative to synthetic fertilizers because they are environment friendly, increase seed germination, soil fertility, nutrient utilization efficiency and yields [1]. The synthesis and development of NFs are based on a sustainable alternative to existing, posh, and environmentally harmful traditional synthetic fertilization techniques [2]. Biosynthesized NFs are the newest and most technologically sophisticated methods of providing crops with mineral nutrients. The capacity of a biological process to tightly regulate the form of the particles would be a significant benefit [3].

As part of their metabolic requirements, these bacteria can directly create NPs or microbial inoculants. These biological fertilizers could potentially have been created inadvertently as a result of microbial metabolic activity for the creation of energy through anabolic and catabolic reactions [4, 5]. A diverse range of microbes have also been extensively used for the production of NPs and microbial inoculants. Nano-biofertilizers are a conjugate preparation which involves the combination of nano- and bio-fertilizers to obtain enhanced crop yields for agro-environmental sustainability [6]. NBFs can protect global food security for rapidly growing populations. Bio-inoculation of NPs with biofertilizers enhanced plant growth promotion under natural and stressed environmental conditions [7].

Bioresources employed in the production of NPs require the selection of the most practical microbes in terms of growth rate, enzyme production, and the appropriate metabolic pathways characterises the manufacture of NPs [8]. The production of metallic nano-particles (MNPs) is carried out by bacteria, viruses, fungi, yeasts, and algae [9]. The molecules such as enzymes, proteins, and polysaccharides are used as reducing and stabilizing agents in the production of NPs. They can be used in the procedure as whole-cell microorganisms, unpurified enzymes derived from microorganisms, unprocessed cell preparations, or crude enzymes.

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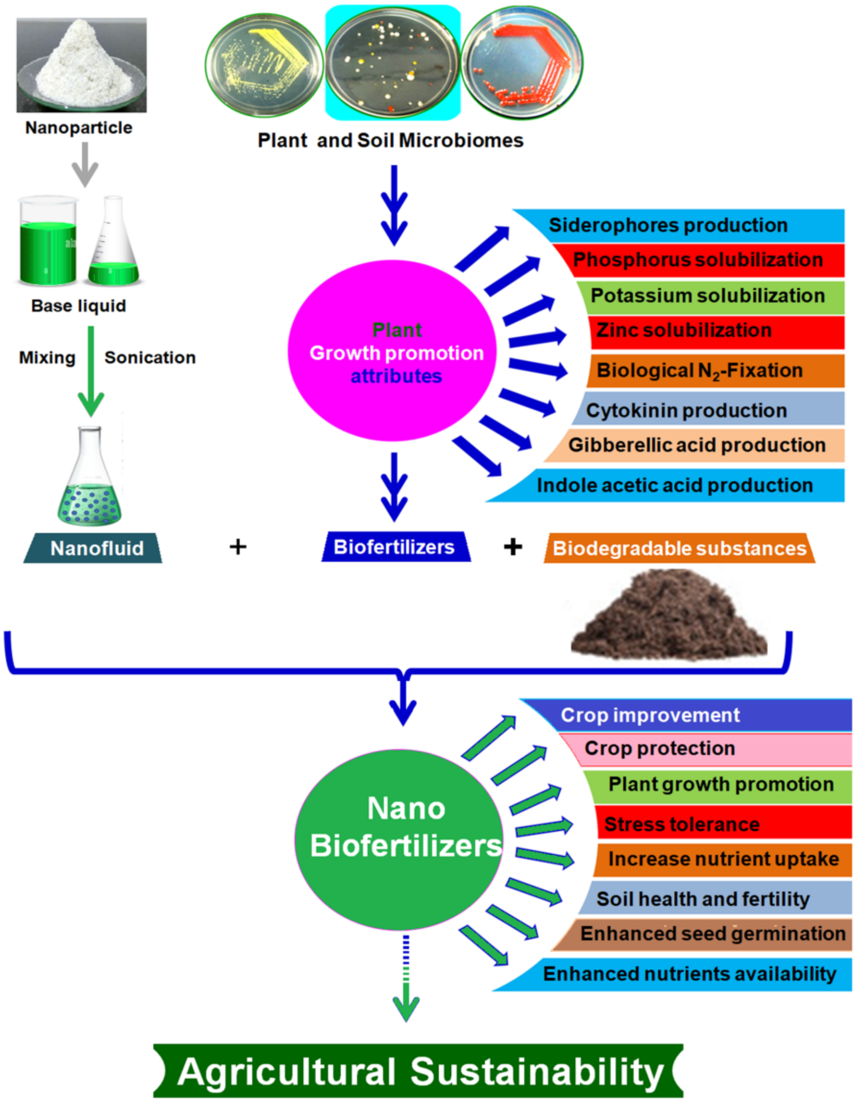

Figure 1: Nano-biofertilizers for agricultural sustainability

The primary cause of the generated NPs is bioreduction, which is carried out by co-enzymes such NADH, NADPH, and FAD [9].

There are many reactions which promotes NPs biosynthesis. To prevent undesirable by-product reactions, the process of this biosynthesis is started with harvesting of microbial bio-mass, which is related to residual nutrients and metabolites. The production rate and product yield are of particular relevance throughout the scaling up operations, and requires optimization (e.g. production time, pH and temperature) [10]. Microbial extra-cellular enzymes are used in the environmental friendly manufacture of nano-biofertilizers to break down the corresponding salts into NPs [11]. Additionally, organic polymers can be crucial to ecosystems by preserving soil moisture after aggregating soil particles and other biologically significant components [12]. Extracellular polymeric substances (EPS) are also crucial for cell adhesion, cell aggregation, and the development of biofilms, which shield cells from a hostile environment [13].

Myconanotechnology has become a fascinating topic where it is possible to use fungi to create nanoproducts that are highly useful in the agricultural industry [14, 15]. Due to their superior effectiveness in producing both external and intracellular enzymes as compared to other microorganisms like bacteria and actinomycetes, fungi play a leading role in the manufacturing of nano-particles [16]. The fertilizer has the ability to accelerate the growth of soil-beneficial microbes, increase the activity of related enzyme systems, improve the overall fertility of the soil, enhance the environmental quality of the soil, and facilitate improving crop quality [17-19]. It also has the ability to increase effective utilisation rates of N, P, and K by 30% and reduce loss by 50% products and increase crops' resilience to disease; it also has the impact of killing insects, somewhat reducing the consumption of pesticides and the like; considerably reducing pollution sources; and, obviously, it has the function of lowering costs and the like [20].

Using algae, actinomycetes, bacteria, fungi, yeast, and plants in the biosynthesis of nano-materials has opened up a new field of study for the production of inorganic and organic bio-nanoparticles as environmentally benign nano-biofertilizers [21]. These NPs enter plant tissue through the stomatal or vascular systems, where they may improve metabolic processes that increase crop yield. Due to its huge size exclusion limit and fast transport velocity, it is believed that the stomatal route is extremely capacitive [22]. These biologically produced, incredibly small functional nano-particles are water soluble fungal proteins that are encapsulated. They are water soluble, somewhat stable, easy to treat downstream and ecologically friendly [23]. Microorganisms could be used for synthesizing bio- and nano-biofertilizers. Due to the potential uses in nano-medicine, the production of nano-particles using biological systems is also the subject of extensive investigation [2].

Nano-biofertilizers can be made using one of two ways, which includes mixing the inoculum with both solid and liquid carriers. Regarding solid carrier materials, they have benefits in boosting the amount of nutrients like phosphorus that plants receive, biologically degrading organic contaminants, and enhancing plant resistance to soil-borne plant diseases [24]. Numerous inorganic and organic materials, including talc, press mud, vermiculite, alginate beads, charcoal, perlite, and peat formulations, have been utilised as transporters. Additionally, it is said that each gram of a carrier for biofertilizers needs to have at least 10 million viable cells of a certain strain. The benefits of liquid inoculants, on the other hand, have been reported to include the fact that they do not require any sticker materials, require less inoculant, support a greater number of cells for a longer period of time, are simple to produce, sterilise completely to prevent contamination, can be applied as fustigation, are compatible with contemporary agricultural machinery, and can be used to reduce stress [25].
There are different carriers which can be used to deliver the nano-biofertilizers. Soils (such clays, peat, coal and inorganic soil), plant waste products (including composts, wheat bran, soybean meal, peanut oil, and farmyard manure), materials that are inert (such as alginate beads, poly-acrylamide gels, vermiculite, powdered rock phosphate, and calcium sulphate), simple oil-dried bacteria and lyophilized microbial cultures, Capsule-based carriers, such as contaminated spores and cells in capsules, and liquid carriers (such as broth, broth + polyvinyl pyrrolidone) are the carrier for the delivery of nano-biofertilizers [26].

Nano-biofertilizers are thus beneficial for the crops. There is a need to develop emerging technologies such as agri-nanotechnology which will contribute to creation of economical and eco-friendly nano-biofertilizers. Presently though nano-biofertilizers do not have appropriate academic and industrial recognitions but in order to achieve nutrient security on limited land and resources, the concept of innovative biotechnology and nanotechnology for sustainable crop production will always be appreciated.

CONFLICTS OF INTEREST

Author declares that there are no conflicts of interest.

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