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NANO-BIOFERTILIZERS FOR SUSTAINABLE AGRICULTURE

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Introduction

Conventional fertilizers play a key role in increasing global agricultural production. The world consumption of three major nutrients viz., nitrogen (N), phosphate (P) and potash (K) have increased consistently over the past years especially after green revolution. Over the period of time, application of chemical fertilizers above threshold limit leads to decreased soil fertility, lesser crop yield, emergence of pests and disease, loss of biodiversity and environmental pollution. Imbalanced application of chemical fertilizers also causes low nutrient use efficiency, high mineral leaching, low nutrient assimilation potency, depletion of organic matter content and deficiency of secondary and micronutrients in soil and plant. Too much dependence on chemical fertilizer like ammonia, urea, nitrate or phosphate compounds in agriculture leads to severe damage to both environmental ecosystem as well as animal and human health. This has made the environmentalists and agricultural scientists to search for a nontoxic eco-friendly alternative to achieve the desired goal, to increase the agriculture productivity without associated side problems. Biofertilizers have emerge out a promising tool and act as supplementary, renewable and eco-friendly source of plant nutrients. The global bio-fertilizer market was valued more than the USD1.49 billion in 2019, growing at a compound annual growth rate (CAGR) of around 12.8% from 2020-2027.Currently, nitrogen-fixing bio-fertilizers represent the biggest segment dominated the global bio-fertilizer market with a share of 71.2% in 2019 followed by phosphate fixing bio-fertilizers.Biofertilizer mainly constituted of live formulations of beneficial microorganism which when applied to seed, plant surface or soil, promote plant growth by increasing the supply of essential nutrients to the plants. The most commonly used biofertilizers are:

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1. Nitrogen fixing biofertilizers
   a. Free living: *Azotobacter*
   b. Symbiotic: *Rhizobium*
   c. Associative symbiotic: *Azospirillum*
2. Phosphorous solubilizing biofertilizers
   a. Bacteria: *Pseudomonas striata*
   b. Fungi: *Penicillium spp. Aspergillus spp*.
3. Phosphorus mobilizing biofertilizers
   a. Arbuscular Mycorrhiza: *Glomus spp.*
   b. Ectomycorrhiza: *Amanita spp.*
   c. Endomycorrhiza
4. Plant growth promoting rhizobacteria
5. Biofertilizers for micronutrients

Nitrogen fixing bacteria are most commonly used biofertilizers as plants do not have the ability to convert atmospheric nitrogen to ammonia, which is essential for their growth and development. Azotobacter, Rhizobium and Azospirillum are the majorly used nitrogen fixing bacteria.Rhizobium has the ability to develop symbiotic association with the roots of legumes, due to which it is used as biofertilizer in the cultivation of leguminous crops. On the other hand, aerobic nature of Azotobacter along with its neutrality in alkaline soil has increased its application scope in the cultivation of crops including maize, wheat, cotton, mustard, and potato. Bacillus, Pseudomonas and Aspergillus are mainly phosphate solubilizing biofertilizers. They accelerate the process mediated by the microbes in the soil and enhance accessibility of phosphorus to plants. Apart from these, multinational companies are also focussing on mass commercialization of potassium mobilizing biofertilizers, zinc solubilizing biofertilizers and NPK consortia. Yet, use of biofertilizers in agriculture comprises some major problems such as poor shelf-life, specific biofertilizer for specific crop, instabilityin field due lack of prescribed soil and environmental conditions (temperature, radiation, pH sensitive), require specific storage conditions, limited availability of beneficial microflora, susceptible to desiccation and large dosage etc. The key market

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trend need production of advanced biofertilizers that are suitable for sustainable agriculture and are efficient in improving plant tolerance and soil fertility.

To overcome all these constraints nanoparticle-based formulations of biofertilizers have been developed to get more efficient and enhanced productivity of crops. The nano-particles are preferred due to their size dependent qualities, unique optical qualities, high surface to volume ratio, high absorption capacity and controlled release kinetics which make them potential plant growth promoter and plant protector. In nano-biofertilizer formulation, biofertilizer (containing nutrients and plant growth promoter bacteria) is coated in nanoscale polymers and this technique is known as nanoencapsulation. Thus, "Nano-biofertilizer" is defined as a hybrid combination of nano and biofertilizer developed by the formulation of organic fertilizer (biofertilizer) to nanosize (1–100 nm) with the help of certain nanomaterial coating. The materials used to make nano particles are metal oxides, ceramics, silicates, magnetic materials, semi-conductor quantum dots, lipids, polymers, dendrimers and emulsions. The nano materials (chitosan, zeolite and polymers) used for coatinghelp in the slow and constant release of nutrients to plants. The nanoparticles act as versatile tool to protect biofertilizer components containing plant growth promoting rhizobacteria (PGPR) thereby enhancing their shelf-life. This technology can be used effectively in integrated nutrient management package as it allows proper distribution of bio fertilizers along with chemical fertilizer formulations. It also helps in slow and steady release of PGPR to crop plants without any inadvertent loss. This technology will benefit the farmers in long run not only by improving the nutrient release characteristics and field performance but will also minimize the cost of production. It can increase the nutrient use efficiency of major nutrients (N, P and K) and can reduce application losses. This technique can also enhance the efficiency of indigenous microbial population through utilization of essential nutrients. It will improve the activity of related enzymes thereby improving the soil fertility thus, improving quality and disease resistance of crops. The plant growth promoting rhizobacteria with other soil microflora like fungi and algae perform variety of activities in soil like phosphorus solubilization and nitrogen fixation. They also produce siderophores, ammonia and hydrogen cyanide, enzymes and phytohormones thereby regulating plant nutrition and their growth rate. Application of bio-nanofertilizer results in a threefold increase in nutrient use efficiency and on an average 80–100 times fewer requirements than chemical fertilizer. The nano

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biofertilizers application to 12 different crops (including cereals, legumes, pulses, and vegetables) showed 10 times more stress tolerance by the crops with 30% more nutrient mobilization in their rhizospheres. The beneficial enzyme activity has been increased up to 283% in different crops resulting in better soil health and native nutrient mobilization. The yield in all the crops was improved between 17% and 54% depending on crops, soils, and type of nano nutrients applied.

Advantages of nano-biofertilizers

- Nano formulations may enhance the stability of bio-fertilizers and bio-stimulators with respect to desiccation, heat, and UV inactivation
- Nanoparticles synthesized by microbes are highly stable, non-toxic, cost-effective and eco-friendly over chemicals.
- Nano-biofertilizer promoted plant growth and nutritional quality.
- Nano-biofertilizer augment the soil nutrient status by various mechanisms like nitrogen fixation, solubilization and mobilization of phosphates, production of siderophores and synthesis of plant hormones.
- Application of nano-biofertilizer can increase plant yield and quality by improving photosynthesis, nutrients absorption efficiency, photosynthate accumulation and nutrients translocation to the economic parts.
- The nano-biofertilizers improve germination capacity of legume crops by providing doped nutrients in efficient manner especially those containing neem cake and PGPR.
- It minimizes the loss of soil nutrients by leaching, gasification, soil erosion, competition with other organisms leading to enhanced nutrient absorption and assimilation by plants.
- The PGPR in nano-biofertilizer (bioorganic component) help in nitrogen-fixation, phosphate-solubilizing and help in restoring soil fertility whilenanomaterials help in the slow and steady release of nutrients as per crop demand in a synchronized mode.
- It also increases resistance against pest and disease pathogens in plant by acting as resistance inducing agent. The nano claycoated biological agent like Trichoderma sp. and Pseudomonas sp. are used to control fungal or nematode disease in rabi crops. It also provides crop resistance against abiotic stresses.

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- One litre of nano-biofertilizers can be used in several hectares of crops, therefore required in very small amount as compared to chemical fertilizers.

Drawbacks of nano-biofertilizers

- The risks of nano-biofertilizers should be evaluated prior to use in open agricultural ecosystem as some nanomaterials have toxic effects. Prefer nano material which are non-toxic, biocompatible and biodegradable.
- The production and availability of nano biofertilizers is limited which influence its large-scale adoption as a source of plant nutrients.
- The high cost of nano biofertilizers compared to conventional biofertilizers
- Lack of standardization in the formulation process. This brings about different results of the same nanomaterial under various pedoclimatic conditions.
- The synthesis of nano particle depends on choice of microorganism which vary with respect to growth rate, enzyme production and metabolic pathways.
- During process of optimization various factors like production time, pH, temperature etc can influence the particles morphology and their properties. Therefore, optimal reaction conditions as well as equipment's required for bio reduction are important.
- Lack of technical expertise
- Labour-intensive technique

Future perspective

The excessive use of chemical fertilizers in the agriculture sector, which is the most expensive agricultural input and lead to increase the crop production reflect variety of negative impacts including environmental and ecological pollution. Therefore, to develop an eco-sustainable way to improve agricultural productivity a strategy is developed which have least side effects. Nanotechnology presents a solution through nano biofertilizers which have a promising future in the field of sustainable agriculture management. Nano biofertilizers will act as a potential "nutrient booster" allowing the slow and sustained release of nutrients to plants throughout the growth period. Wherever possible, organic manures and other organic materials should be used in an integrated fashion with nano-based fertilizers to ensure efficient and effective nutrient use as well as better soil health. Nano-biofertilizer could promote several benefits to plants, i.e., slow-release characteristics, enhanced stability of functional ingredients, use of small dose, limited nutrients loss by degradation and leaching, masking soil nutrient depletion and improving crop yield attributes. Hence, nano biofertilizers are considered as future of sustainable agriculture as they are intrinsically environmentally friendly as well as economical. However, the risk of nanomaterials must be assessed prior to use for safe application of this technology in agriculture.

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