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SYNTHESIS, APPLICATION AND PROSPECTS OF NANO-BIOFERTILIZERS: A REAPPRAISAL

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Agriculture has been the first source of food for living organisms since earlier period. With the continuous increase in world population, it's becoming difficult to fulfil the stress of food by using the standard fertilizer. Except this, the use of standard fertilizers has decreased the standard of food products due to degradation in soil fertility and stability. The use of modern technologies like nanotechnology and biotechnology in agriculture sector might help in increasing productivity as well quantity of the crops grown. The formulation of nanotechnology with biotechnology is one in all the best advancement in research, thanks to its various beneficial effects achieved by the use of nano-biofertilizers in fields. Nano-biofertilizers have gained the attentionof the scientist for development of a sustainable and eco-friendly approach towards the agriculture sector, overcoming the use and effects of chemical fertilizers and biofertilizers alone. With the growing demands of food and therefore loss of soil stability, the utilization of nano-biofertilizers has become the requirement of the hour. The synergistic action of both the nanoparticles and the bioorganic component has tremendously affected the growth and expansion of plants, increased soil fertility and stability and provided resistance to pathogens and pests. This review focuses on the applications and formulations of the nano-biofertilizer in agriculture sector and also promotes its use for sustainable future generations.

Keywords: Nano-biofertilizers, Nanotechnology, Biotechnology, Sustainable agriculture

Introduction

The use of chemical fertilizers in agricultural fields is increasing day by day to satisfy the food demands of the over-growing population of the world[1]. These fertilizers are helpful in increasing the yield and productivity of the crop but their excessive use is proved to be harmful for future generations resulting in environmental pollution, loss of biodiversity, emergence of pests, nutrient loss and its biomagnification in humans resulting in damaging major organs and organ systems[2]. Other than this, these chemical fertilizers contribute towards the eutrophication in water systems and its deposition in soil results in reduction in growth of plants, increased salinity and depletion in soil fertility, soil nutrients and water holding capacity of plants[3].These cause irreplaceable damage to the soil structure and also disturb the equilibrium of the food chain across the ecosystem which can cause genetic mutations in consumers of future generations[4].To overcome these effects caused by the chemical fertilizers, scientists are developing an eco-friendly approach that is the use of safe eco-friendly alternatives – Nanotechnology.

Nanotechnology has emerged as the sixth most revolutionary technology

after green revolution and biotechnology revolution. To transform the traditional agriculture farming practices into modern agriculture and to ensure better food security among the individuals, the scientists are combining the two technologies together to attain a particular result which might be more eco-friendly and sustainable[5]. These two technologies include the nanotechnology and also the biotechnology withinwhich the nanotechnology is combined with biofertilizer- Nano-biofertilizer which is coming as an innovative field of agriculture. Nano-biofertilizer is a hybrid of the two 'the nano' and 'the biofertilizer' developed by the formulation of organic (biofertilizer) to nanosize (1-100nm) with the assistance of certain nanomaterials which are used for coating[6].

Some researchers consider nano-biofertilizers as 'cocktails' because of its high efficiency in providing fertilizer benefits, helping in promoting crop yield and productivity because of slow release of nutrients for an extended period of crop growth stages[7]. The salient features of a nano-biofertilizer are (i) enhanced nutrient use efficiency and absorption,(ii)cost effective, (iii) mass scale production at a short span of time, (iv)low quantity of fertilizer is required at large scale,(v) eco-friendly, (vi) promote plant growth and (vii)provide resistance against diseases[8].The use of nanotechnology in producing a potent nano-biofertilizer is itself an innovative approach because the use of biofertilizers alone had a number of disadvantages like poor stability and efficiency, poor shelf life, poor performance under fluctuating environmental conditions and requirement of high dosage for a bigger field area.

Nano-biotechnology has gained a rapid momentum within the agriculture sector by emerging as a tool to market providingboth growth and productivity by developing ultra-small particles having unique features like physicochemical properties and surface area to volume ratios[9]. These nano-materials have varied application in agriculture sector including the protection of plants, high nutrient quality and management in farm because of its small size and better surface to volume ratio[10]. These nano-particles are made from a good range of materials like ceramics, magnetic materials, quantum dots, polymers, metal oxides, lipids, semiconductors, emulsions and dendrimers[11]. For seed treatment and also as bio-pesticide to treat fungal infections chitosan nanoparticles are being used. The uptake of nanoparticles and its efficiency in growth of the plant varies from species to species. Also, the concentration of nanoparticle used for a specificplant affects its metabolic processes[12].

Synthesis of Nano-biofertilizers

The synthesis of nano-biofertilizers is done using novel methods which are environmental friendly and involves the major usage of biological entities without the involvement of any toxic chemicals. The biological entities involved in the synthesis of these nano-particles are mainly microbes because of their potential to produce inorganic materials intra-cellular or extra-cellular such as the use of diatoms for siliceous materials, magneto static bacteria for magnetite and S-layer bacteria for gypsum and calcium carbonate[13]. This nano-biotechnology has resulted into the increase in the biomass production and sustainability of the agriculture[14]. The formulation of nano-fertilizers should be done in such a way that it should comprise of all the desired properties including high solubility and stability, effectivity, enhance targeted activity with effective concentration, easy delivery and disposal, time –controlled release and eco-friendly nature[15].The use of fungi in development of myconanotechology has also gained attention of the scientists because of its potential to form more intracellular as well as extracellular products in comparison to the bacteria and actinomycetes[16,17].

The nanoparticles used for the delivery of nutrients to the living systems possess great potential and the loading of nutrients on these nanoparticles is done through various ways which includes attachment, absorption, encapsulation, entrapment, ligand mediated and synthesis. It is observed that the slow release of nutrients from the nano-fertilizers takes place which is effective in plant growth as compared to the commercial fertilizer[18]. In nano-biofertilizer formulation, biofertilizer is coated with nano-scale polymer which is a type of encapsulation method. The biofertilizer contains nutrients required for the growth of plant and also the plant growth promoting bacteria[19].

The nano-encapsulation technology is used as a versatile tool to protect the biofertilizer components containing plant growth promoting rhizobium to enhance the dispersion of fertilizer formulation, to enhance their shelf life and to allow the controlled release of the plant growth promoting rhizobium[20]. The use of nano-biofertilizers has helped farmers in an intensified way by improving the field performance, by release of nutrients and also by reducingthe capital cost needed for the fertilizers and pesticides. It has proved to be a renewable, eco-friendly and sustainable approach which accelerates the efficiency of the nutrient utilization such as nitrogen, phosphorus and potassium, improve the fertility of the soil, enrich the microbial population beneficial for soil, improve the crop quality and provide resistance from disease causing organisms. The uptake of nanoparticles by plants is mainly done by two mechanisms (i) by direct entry of nanoparticles into the plant cells through pores on the cell wall and (ii) involves the dissolution of nanoparticles which are then absorbed through the roots of the plants and released as soluble ions. Also, this dissolution in soil or water is higher because of its small size and increased surface area as compared to the conventional fertilizers[21].These nanoparticles can be made up of hydroxyapatite, TiO_2, SiO_2 or even carbon nanotubes[22].

Applications of Nano-biofertilizers

(I) *In improving nutrient status and plant growth:*

The use of nano-biofertilizer exerted a diversified effect on the plant growth and soil. The formation of nano-biofertilizer is done with the help of nano-encapsulation method in which the nanomaterials are used such as chitosan, polymers, zeolite which help in the slow and sustained release of the nano-encapsulated organic materials[23]. The nano-particles are coated onto the surfaces of the biofertilizers to increase its stability. The active uptake of nutrients by the crop at different stages of the plant growth is enhanced because of its nano-size, increased surface area and enhanced interaction due to the presence of high reactive NP-coated fertilizer.

Bioorganic components used in the nano-biofertilizer formulation such as the Plant Growth Promoting Rhizobium and fungal inoculants benefit the soil by enriching its nutrient quality and fertility by means of various methods like (i)by fixation of atmospheric nitrogen by rhizobium via plant root, (ii) by production of metal chelating elements like siderophores which make metal available for the plant root, (iii) by presence of phosphate solubilizing bacteria and fungi which help in solubilisation of the available phosphates and (iv) by synthesis of pytohormones[24,25].

(II) *In promoting the physiological and morphological development of plant:*

Nano-biofertilizers optimizes the nutrient absorption efficiency, rate of photosynthesis, nutrient translocation to the aerial parts of the plant and higher photosynthate accumulation thereby increasing the plant growth, productivity and quality. It was observed that the use of nano-biofertilizers developed by entrapping of the growth promoting microorganisms like *Pseudomonas fluorescens, Bacillus subtilis and Paenibacillus elgii* within the gold and silver nano-particles on the agricultural

crops proved to be effective in promoting the growth of the various crops as compared to the use of nano-fertilizers applied alone[26]. It was also observed that the productivity in some leguminous crops was increased by the use of nanostructured fertilizer containing the neem cake and plant growth promoting rhizobium because of which there was stimulation in the germination potency of the crop seedlings and the delivery of nutrients to plants was done in an efficient manner[27].

(III) *In increasing the nutritional security in plants:*The continuous use of chemical fertilizers has resulted in nutrient loss from the soil making it unfit for the growth of the plants. The major challenges faced by the farmers at present is the low soil fertility and the nutrient content depletion of the soil because of which there is a huge decline in the crop productivity and nutritional value of the crops[28]. To overcome these problems nano-biofertilizers are used which provide sustainable, low-cost and efficient nutrient management. It has minimized the soil nutrient loss by leaching, gasification or competition with other organisms and has increased the nutrient absorption and assimilation capacity of the soil as well as plants[29]. Also, the bioorganic components present in the nano-biofertilizer helps in restoring the richness of the soil by nitrogen –fixation and phosphate solubilisation and the nano-particle component helps in the slow release of the nutrients in a proper manner as per the demand of the crop[30].

(iv)*In protecting crop against pests and pathogens:* Nano-biofertilizers also play a significant role in providing resistance to the crop from disease causing pathogens and pests. There are many instances in which nano-biofertilizers were used to treat the diseased crops. For example in tomato crops infected with bacterial wilt disease caused by the *Ralstonia solanacearum* against the wilt causing microorganism[31]; in leguminous plants the bioorganic components of the nano-biofertilizers acts as defence for the plants protecting them against different pathogens[32]; use of titanium nano-particle coated nano-biofertilizer helped in protection of plant against harmful fungal infections[33]; in rabi crops, the use of nano-clay coated biological agent containing *Trichoderma* and *Pseudomonasspecies* are used to control the disease caused by fungi and nematodes[34]. When an obligate symbiont, Arbuscular mycorrhizal fungihave shown promising results as a modest biocontrol agent, when compared to chemical fertilizers and pesticides, then nano-biocontrol agents and biofertilizers will definitely steal the show[35]. Therefore, the nano-biofertilizers act as a safe-guard for the crops protecting them against disease causing pathogens and pests.

Future Prospects

The present review focuses on the utilization of nano-biofertilizer for the agriculture sector so as to obtain a sustainable and eco-friendly approach towards it. The combination of these two technologies has proved to be beneficial for the growth of the plant. Scientist should focus more on using those biological agents which might benefit the crop in the long term. There should be application of the developed nano-biofertilizer in natural environment to urge a definite depiction of the impact caused by nano-particle in environment. Also, there should be proper exploration and management of the shortcomings of the bioorganic used and there should even be a correct validation of the nano-particle used as per the government and scientific based safety assessment in making of the nano-biofertilizer. Thus, the development of nano-biofertilizer can be beneficial and effective in solving the current food problems of the organisms for the long-term period.

Conclusion

The continuous and increased use of chemical fertilizers and pesticides by the farmers has resulted in decrease in soil fertility and growth of the plants which

ultimately led to the low quality and quantity of the food generated from those crops. Due to increasing problem of food and to overcome the effects of previously used standard fertilizers and pesticides, scientists have combined the two technologies- nanotechnology and biotechnology which led to the combination, Nano-biofertilizers. The development of nano-biofertilizers have proven to change the scenario of the agriculture sector by increasing the soil fertility, nutrient absorption efficiency, plant growth and productivity, resistance against pathogens and pests and also the long-term effect of the bioorganic component used. The methods used by the scientists to develop nano-biofertilizers has impacted the soil stability and sustainability in different ways and has proved to be cost-effective, eco-friendly and sustainable for future generations.

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