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# Nanofertilizers vs. Biofertilizers: New Insights

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BIO- and nano-fertilizers are one of the most important tools in modern agriculture and agri-food as well as a driving economic force in the near future. Also, bio-and nano-fertilizers also play an important role as promising methods for increasing use efficiency of different water and land resources, reducing environmental pollutions as well.So, environment friendly biotechnological approaches may offer alternatives to chemical fertilizers. Types of bio-fertilizers such as *Rhizobium, Azospirillum, Cyanobacteria, Azolla, Azotobacter* and *Acetobaceter* as well as P, K and Zn solubilizermicrobes are the most important microbial traits in soil biogeochemical cycles and plant growth promotion.The biosynthesis of nanomaterials using bacteria, algae, yeast, fungi, actinomycetes and plants has led to a new area of research for the formation of inorganic nanoparticles as eco-friendly fertilizers. Now, use of nanofertilizers in plant nutrition is one of the major roles of nanotechnology in agriculture and soil sciences. Thus, the application of biosynthesized nanoparticles in agricultural sector may lead to sustainable development. Hence, this leads to sustainable agriculture through putting less inputs and generating less wastes, minimizing nutrient losses, and release nutrients at a proper rate for plant demand comparing with conventional farming. There is very slight difference between bio-and nano-fertilizers depending on their mechanisms in the soil and plant, application methods, effective rates of addition as well as their impact on the environment. However, both nano-and bio-fertilizers and their interaction are needed further studies. Therefore, this review will focus on the new insights and a comparison between both nano- and bio-fertilizers.

**Keywords:** Biofertilizer, Nanoparticles, Biosynthesis, Fertilizers, Nanofertilizer, Plants.

## Introduction

Around the past six decades, the application of chemical fertilizers has played a crucial role globally in increasing crop yield and maintaining adequate food supplies(Meena et al. 2016; Chaudhary et al. 2017). Several investigations concerning the long term experiments using chemical fertilizers and their impacts on agroecosystem have been published (Chaudhary et al. 2017; Ding et al. 2017). The management of crop production and landscape had created a large-scale market for chemical fertilizer consumption. However, these land-use practices subsequently encountered environmental challenges because of the low fertilizer use efficiency and subsequent nutrient release into the surface or ground water as well as emission of gases into the atmosphere (Drechsel et al. 2015). Concerning the problems of chemical fertilizers, many problems have been reported including atmospheric and groundwater pollution, soil acidification, eutrophication, decline of soil fertility, loss of biodiversity and high consuming of energy in synthesis processes (Tomer et al. 2016; Mahanty et al. 2017; Kourgialas et al. 2017). Therefore, over the last decade, great efforts have been taken to replace the chemical fertilizers with environmental friendly bio- and nano-fertilizers (Liu and Lal 2015; Davarpanah et al. 2016; Mikhak et al. 2017).

Biological fertilizers(referring here to bio-fertilizers and biosynthesized nano-fertilizers) are the newest and most technically advanced way of supplying mineral nutrients to crops. A biological process with the ability to strictly control the shape of the particles would be a considerable advantage. Extracellular secretion of the microorganisms offers the advantage of obtaining large quantities in a relatively pure state, free from other cellular proteins associated with

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the organism with relatively simpler downstream processing. The use of specific enzymes secreted by fungi in the synthesis of nanoparticles appears promising. Compared to chemical fertilizers, the supply of biological fertilizers of nutrients for plant needs, the minimizing leaching and therefore improving fertilizer use efficiency (Subbarao et al. 2013; Malusà et al. 2016; Pandey and Chandra 2016). Therefore, there is a pressing need to develop safe, cost effective, reliable, clean, non-toxic and eco-friendly methods for the preparation of nanoparticles and microbial inoculants as well. Furthermore, biosynthesis using organisms is compatible with the green chemistry principles, where the bio-organism should be (i) eco-friendly (ii) reducing agent and (iii) capping agent (Elkhatib et al. 2015; Hussain et al. 2016; Bagherzade et al. 2017).

It is well known that, microorganisms are known to contribute to the formation of biological fertilizers including bio- and nano-fertilizers (Liu and Lal 2015; Tomer et al. 2016; Malusà et al. 2016; Pandey and Chandra 2016; Mahanty et al. 2017; Mikhak et al. 2017). These microorganisms can directly produce nanoparticles or microbial inoculants as part of their metabolic requirements. It could be also formed these biological fertilizers indirectly as a result of microbial activity for production of metabolic energy through redox reactions (Patil and Solanki 2016). As a result, the biosynthesis of these biological fertilizers could be mediated by biological systems including bacteria, fungi, actinomycetes and plant extracts (Yadav et al. 2015; Panpatte et al. 2016). Therefore, these biological fertilizers can efficiently work as biocontrol/biofertilizer agent in field. With respect to the microbe selected for nanoparticles and microbial inoculants synthesis, the selected microbes can control various diseases, individually and in combination with other microbes as biofertilizer/ biocontrol agent. Moreover, several microbes have been widely used for the biosynthesis of nanoparticles and microbial inoculants as well (Belal and El-Ramady 2016; Mani and Mondal 2016; Shalaby et al. 2016; Thilakarathna and Raizada 2017).

The interactions among plants, nanoparticles (like nano-fertilizers) and microorganisms (as biofertilizers)may need further studies. These interactions may include (1) the positive effects of biofertilizers (or the agriculturally beneficial microorganisms) in alleviating the nanoparticles toxicity(Boddupalli et al. 2017), (2) the response of plants to nanoparticles or nanofertilizers (Siddiqi and Husen 2017b), (3) the close relationship between plants and biofertilizers (Tomer et al. 2016; Mahanty et al. 2017) and the role of plants and microbes in biosynthesis of bio- and nanofertilizers (Siddiqi and Husen 2017a). Future strategies also are needed to focus on understanding the interactions of biofertilizers from bacteria with nanoparticles, which also serve as useful micronutrients for microorganisms and plants. In the present review, the similarities and differences between bio- and nano-fertilizers will be discussed as well as developments in plant and soil sciences. The role of these fertilizers in plant growth and development will be also highlighted as well as their mechanism, biosynthesis, types and beneficial for plant and soil.

*Definition of nano- and bio-fertilizers*

The development of this new kind of products has prompted the need to define exactly what the term means. Indeed, the term has been defined in different ways during the past twenty years, which reflects the development of our understanding in the relationships between the microorganisms and the plants (Table 1). Concerning the biofertilizers, they could be defined as microbial inoculants, in which live or dormant formulations of beneficial microorganisms can enhance and promote plant growth (Malusá and Vassilev2014; Sultana 2016; Pandey and Chandra 2016; Kulkarni et al. 2018). Biofertilizers could be also called as microbial cultures, bioinoculants, bacterial inoculants, or bacterial fertilizers. These biofertilizers also could be included $N_2$-fixing biofertilizers, P-solubilizing biofertilizers, P-mobilizing biofertilizers, biofertilizers for micro- or beneficial nutrients and plant growth-promoting rhizobacteria(Singh et al. 2014a,b).

The common features could be extracted from these definitions include (1) biofertilizers are microbial inoculants or formulations of beneficial microorganisms, (2) they could enhance the plant growth and conserve the mobilizing crop nutrients in the soils and (3) reduce the chances for environmental deterioration. Therefore, biofertilizers contain latent or living cells of proficient strains of some microbes, by which assist crop plants to take nutrients and then accelerate several microbial processes. These microbial processes may help plants to increase the uptake efficiency of nutrients as well as to increase the availability of surface area and cell count of such types of microorganisms through immobilization process on carrier material (Kulkarni et al. 2018).

**TABLE 1. Different common definitions of biofertilizers from different literatures**

| Definition of biofertilizer | References |
|---|---|
| Biofertilizer is a substance applied to seeds, plant surfaces or soil colonizes in the rhizosphere promoting plant growth through increasing the availability of essential nutrients to the host plants | Mazid et al. (2011) |
| Biofertilizers could be defined as biological active products or microbial inoculants or formulations containing one or more beneficial microorganisms like bacteria and fungi enhancing the economical carrier materials, conserving and mobilizing crop nutrients in the soils | Mazid and Khan (2014) |
| Biofertilizer is a formulated product containing one or more microorganisms enhancing the nutrient status through the growth and yield of the plants by availability nutrients to plants and/or by increasing plant access to nutrients | Malusá and Vassilev (2014) |
| Biofertilizer is unique, eco-friendly and cost-effective alternative to the chemical fertilizers improving both the crop productivity and soil health in a sustainable manner | Bisen et al. (2015) |
| Biofertilizer is the formulated product containing one or more beneficial microorganisms, which enhance the nutrient status in the plants by increasing plant availability and uptake to nutrients | Pandey and Chandra (2016) |
| Biofertilizer is a formulation or a preparation containing latent or live micro-organisms having effective and long-term storage, easy in handling and delivering live microbes from factory/ lab to field | Sahu and Brahmaprakash (2016) |
| Biofertilizers could be defined as the microbial inoculants, which colonize the rhizosphere in order to improve plant growth by enhancing nutrient accessibility to plants | Tomer et al. (2016) |
| Biofertilizer is a natural fertilizer containing a large population of specific or a group of beneficial microorganisms for enhancing soil productivity either by fixing atmospheric N or solubilizing soil phosphorus or stimulating plant growth through synthesis of growth-promoting substances or latent cells, which activate the biological process render to facilitate nutrients availability for plants | Simarmata et al. (2017) |
| Biofertilizers are carrier or liquid based products containing living or dormant microbes (i.e., bacteria, fungi, algae, actinomycetes) alone or in combination, which help in fixing atmospheric-$N_2$ or solubilizers of different soil nutrients as well as the secretion of growth promoting substances for enhancing crop growth and yield | Dineshkumar et al. (2018) |

Concerning the nanofertilizers, they could be defined as nanomaterials or nanoparticles by which some essential or beneficial nutrients could be delivered to plants at the nano scale in order to support the plant growth and improve its production (Liu and Lal 2015; Mani and Mondal 2016; Chhipa 2017). It could be divided nanofertilizer into three categories macro- and micro-nanofertilizer, and nano-particulate fertilizer based on nutrient requirements of the plants (Chhipa 2017). It is well known that, through the nanotechnology, it could be manufactured some selective materials to be under 100 nm. These nanomaterials have nanoscale dimension (< 100 nm) and specific functions adding to the soils to supply one or more essential plant nutrients. Therefore, the common features combine between nano- and bio-fertilizers are represented in (1) delivering the proper nutrients for plant growth through soil and foliar applications,(2) a low-cost and eco-friendly source of plant nutrients, (3) a high efficiency for fertilization process, (4) have a supplementary role with chemical fertilizers as well as (5) protecting the environment from pollution risks. Moreover, these biological fertilizers could be considered emerging alternatives for conventional fertilizers and help us to eliminate contamination of drinking water and eutrophication (Guru et al. 2015).

Therefore, it could be concluded that, several definitions have issued regarding biofertilizers, whereas there is a common meaning for nanofertilizer. Both biofertilizers and biological mediated-nanofertilizer have many similar properties mainly represent in the sustaining and conserving the agriculture, reducing the risks of the environmental pollution and cost-effective of fertilization process. There is a crucial need for studying the integration between nano- and bio-fertilization towards safe food and high quality of crop productivity as well as improving the soil health.

*Biosynthesis of biological fertilizers*

*Biosynthesis of nanofertilizers*

Nanotechnology based biofertilizer has the potential to revolutionize the agricultural systems and numerous other areas. Nanoparticles are atomic or molecular aggregates with at least one dimension between 1 and 100 nm, which can drastically modify their physicochemical properties compared to the bulk materials. Due to its high surface area to volume size ratio, they exhibit significantly novel and improved physical, chemical and biological properties, phenomena and functions. Nanotechnology based biofertilizer as bio-tech innovations; it is the matter at nanoscale (1 – 100 nm) dimensions. Bio-materials when reduced to the nanoscale show some properties which are different from what they exhibit on a macro scale, enabling unique applications. In order to synthesis of nanonutrients, microorganism was grown over selected nutrient source and provides necessary growth conditions. After the complete growth the biomass was separated. The filtrate was used for isolation of extracellular specific proteins and these were used for nanoparticle synthesis (Fig. 1). The selection of microorganism and optimum parameter are specific for synthesis for desired type of nanonutrients. Through catalytic effects, microbial extracellular secreting enzymes could produce reducing the metal salt of macro or micro scale into nano-scale diameter. These nanoparticles get into plant cells through either stomatal or vascular system which may enhance plant cell metabolic activities that lead to higher crop production. It is suggested that, the stomatal pathway is highly capacitive because of its large size exclusion limit and its high transport velocity. Such biologically synthesized, very tiny functional nanoparticles are economically chief, relatively stable, easy downstream processing and environmentally safe as they are encapsulated by fungal protein which is water soluble. In general, the synthesis of bio- and nano-fertilizers could be achieved using microorganisms, where some nanofertilizers may result from the biological method. Furthermore, the synthesis of nanoparticles using biological system is in wide research due to the potential applications in nanomedicine. The biological synthesis of nanoparticles is less expensive and eco-friendly (Patel and Krishnamurthy 2015).

As mentioned before, the synthesis of nanoparticles could be mainly achieved through the physical, chemical and biological methods. Concerning the biological method, it could be produced nanoparticles from reduction and oxidation processes from small entities using lesser defects *in-vitro* or *in-vivo*. Several substances mainly could be used as reducing and stabilizing agents during this synthesis process including proteins, enzymes, sugars and phytochemicals such as phenolics, flavonoids, cofactors, terpenoids, etc. It is reported that, some nanoparticles could be used in nano-fertilization, which generated through the biosynthesis process in many studies (e.g., Belal and El-Ramady 2016; Dubey and Mailapalli 2016; Mani and Mondal 2016; Chhipa2017; Khan and Rizvi2017; Okorie et al. 2017).

Therefore, it could be concluded that, biosynthesis of nanofertilizers could be achieved through many microorganisms and plant extracts. Concerning the biological method for nanofertilizer biosynthesis, it could be produced nanoparticles through many bio-tech innovations. Day by day, a great attention will be increased searching about novel methods in preparing the biological mediated-nanofertilizers.

*Production of biofertilizers*

There is an increasing need for eco-friendly agricultural practices such as using of biofertilizers or fertilizers based on beneficial microorganisms or microbial-based fertilizers. It could produce some selected microorganisms (like bacteria) in production of biofertilizers using pure cultures as a quite common practice (Fig. 1). Therefore, once the particular strains for the inoculum have been selected, an industrial standardized process of production can be defined (Schmidt 2005). The cost of production is an important constraint in the production of biofertilizers, considering that their price shall not exceed that of conventional ones to assure the sustainability of market (Malusá et al. 2012). It is reported that, the producing of formulation containing an effective bacterial strain under inoculant industry is a crucial aspect. There are certain considerations should be kept in mind during the production of biofertilizers (Sahu and Brahmaprakash 2016), such as:

(1) The produced formulation should be easy to handle and apply bythe end users,

(2) Inoculant formulation should also be delivered to the target sites inthe most appropriate manner and form,

(3) It should be able to protect the agent from various harmful environmental factors,

(4) It should be able to enhance or maintain activityof the organism in the field,

(5) It should be remain stable during production, distribution, storage, transportation, irrespective of whether product is new or improved,

(6) The cost-effectiveness of the formulation should not put much pressure on the end users financially, and

(7) It should enhance improving soil properties and able to resist pH changes during storage, as reported in several studies (e.g., Malusá et al. 2012; Singh et al. 2014b; Sahu and Brahmaprakash2016; Bharti et al. 2017).

It is worth to mention that, the live microorganisms could be delivered through the carrier. It could be defined the carrier as an inert material using in transporting microbes from factory or laboratory to soil (Brahmaprakash and Sahu 2012; Sahu and Brahmaprakash 2016). These carriers in general should be characterized with certain properties and superior-quality carrier materials for microbial inoculants include:

(1) The carrier should be the major portion of the inoculant to help in delivering the suitable amounts of microbes in a good physiological condition (Smith 1992),

(2) It should be designed to provide a suitable microenvironment for the microbes, easily biodegradable, nontoxic and nonpolluting (Smith 1992; Muresu et al. 2003),

(3) It should be stable at room temperature or it has a sufficient shelf life nearly at least 2-3 months (Bashan 1998; Malusá et al. 2012),

(4) It should be in a good moisture absorption capacity or high water-holding and water-retention capacity as well as suitable for almost bacteria (Mishra and Dahich 2010)

(5) Easy to sterilize by autoclaving or other methods (Keyser et al. 1993),

(6) Low cost, available in adequate amounts and good pH buffering capacity (Keyser et al. 1993; Mishra and Dahich 2010), and

(7) Carrier of inoculants should be proper for surviving the microbes (Muresu et al. 2003; Malusá et al. 2012; Nehra and Choudhary 2015; Egamberdieva and Adesemoye 2016; Sahu and Brahmaprakash 2016).

It could be prepared the formulation of biofertilizer into two methods including mixture the inoculum with solid and liquid carriers. Concerning solid carrier materials, they have advantages in increasing the supply of nutrients like phosphorus to plants, biological degradation of organic pollutants and resistance to soil-borne plant pathogens (Warren et al. 2009). Many inorganic substances and organic carriers have been used as carriers including talc formulation (Manikandan et al. 2010), press mud formulation, vermiculite formulation (Sangeetha 2012), alginate beads (Trivedi et al. 2005), biochar (Hale et al. 2015), perlite (Daza et al. 2000; Khavazi et al. 2007) and peat formulations (Albareda et al. 2008; Kaljeet et al. 2011). Furthermore, it is reported that, each gram of carrier of biofertilizers should contain at least 10 million viable cells of a specific strain. On the other hand, many advantages of liquid inoculants have been reported to include no need for any sticker materials, a less amount of inoculant is needed, high number of cells will be supported for a long time,easy to produce, sterilize completely preventing contamination,a large number of inoculum could be transported in small bottles, applying as fertigation, compatible with modern agriculture machineries, could be used for stress alleviation (Sahu and Brahmaprakash 2016).

Carriers could be divided into the following categories: (1) soils (likeclays, peat, coal and inorganic soil), (2) plant waste materials (such as farmyard manure, composts, soybean meal, soybean, peanut oil, wheat bran and press mud), (3) inert materials (like perlite, vermiculite, ground rock phosphate, calcium sulfate, poly-acryl-amide gels and alginate beads), (4) plain lyophilized microbial cultures and oil dried bacteria, (5) liquid carriers(like broth, broth + polyvinyl-pyrrolidone) and (6)capsule-based carriers such as pelleted spores and cells in capsules (Sahu and Brahmaprakash 2016). It could be summarized that, biofertilizers are vital part in the modern agriculture. There is great progress has been achieved in manufacturing and production of biofertilizers including new active ingredients and new carriers. Several microbes and many

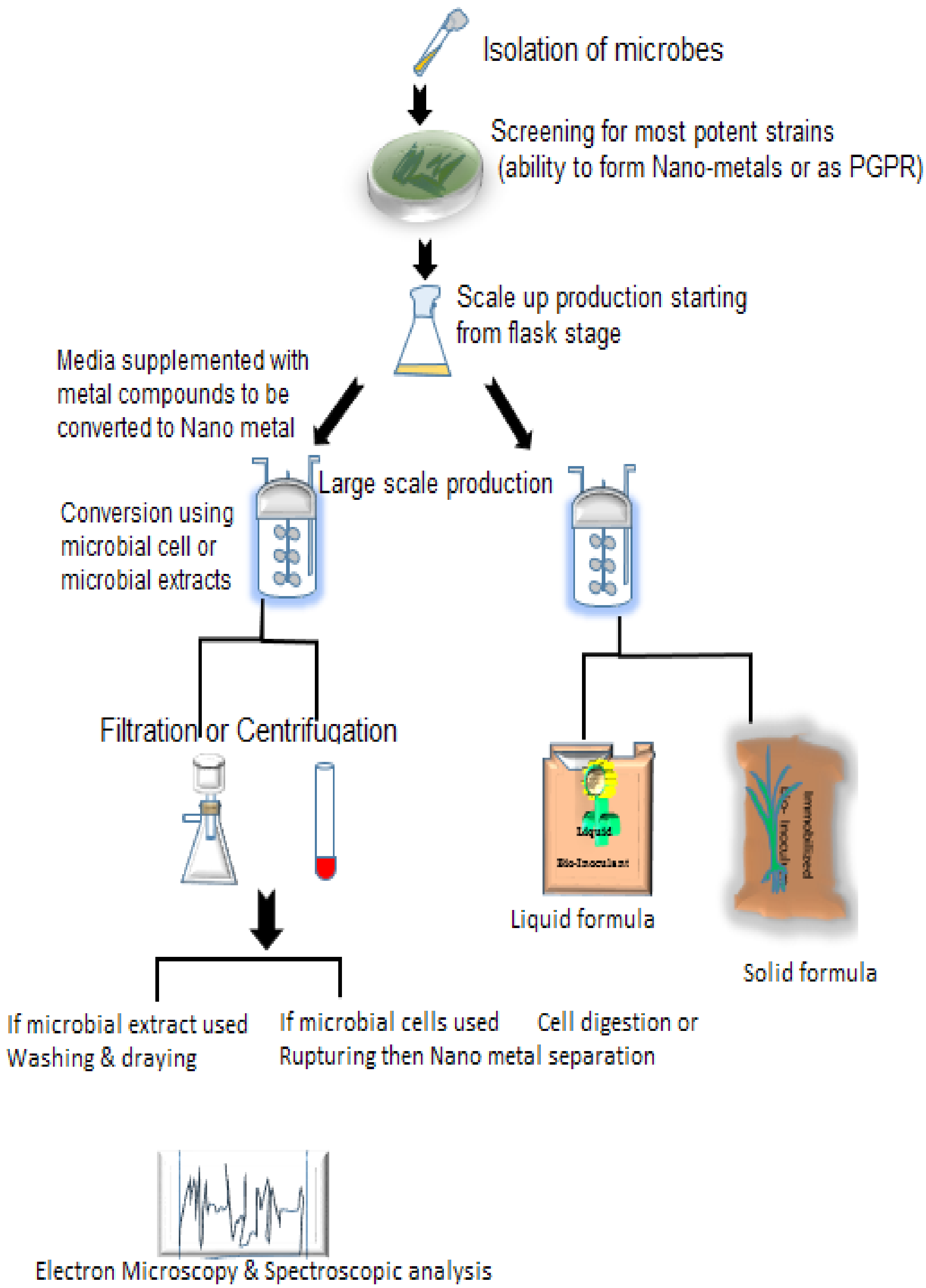


**Fig. 1. General steps could be used in biosynthesis of both bio- and nano-fertilizers, where the first and the second steps could be found for both (isolation of microbes and screening for most potent strains), thereby the scale up production starting from flask stage to produce microbial inoculants through liquid or solid form or to produce nanofertilizer through media supplemented with metal compounds to be converted to nano metal (dedicated by Dr. Tamer Elsakhawy, SWERI, ARC, Sakha, Egypt)**

carriers have been used in producing these biofertilizers.

*Mechanism of nano- and bio-fertilizers*

It is well documented that, the biological fertilizersincluding bio- and nano-fertilizers might enhance plant growth in general through many mechanisms such as (1) the alleviated effects of these fertilizers against biotic and abiotic stresses (like salinity, drought, flooding, etc.) and minimize the negative effects of many plant stresses, (2) promotion the solubilization of nutrients like phosphateby phytase(Sindhuet al. 2014; Suyal et al. 2016), potassium (Ahmad et al. 2016; Raghavendra et al. 2017), zinc (Devi et al. 2016) etc., (3) production phytohormones (i.e., auxins, gibberellins, cytokinins, abscisic acid) in soils enhancing plant nutrition (Mehnaz2015; Wong et al. 2015), (4) plant growth promotion due to $N_2$-fixation (Mehnaz2015; Syiem et al. 2017),(5) managing the soil fertility (Bharti et al. 2017)and (6)sustaining theenvironment (Rashid et al. 2016; Tomer et al. 2016; Panpatte et al. 2016; Mahanty et al. 2017).

*Biofertilizer mechanisms*

As mentioned before, biofertilizers may enhance plant growth by various mechanisms such as production of siderophores, fixation of atmospheric nitrogen that chelate metal elements and make them available to the plant root, solubilization of minerals such as phosphorus, and synthesis of phytohormones. It is worth mentioning that, $N_2$-fixing, phosphate or potassium solubilizing or cellulolytic micro-organisms are used for application to seed, soil or composting areas in order to increase the number of such microorganisms accelerating those microbial processes, increasing the bioavailability of nutrients, which they easily assimilated by plants (Mazid et al. 2011). Biofertilizers may play a very significant role in improving soil fertility by fixing atmospheric N, both, in association with plant roots and without it, solubilize insoluble soil phosphates and produces plant growth substances in the soil. Wong et al. (2015) showed that, the growth promoting factors (phytohormones)in biofertilizers include regulating cell division and its growth as well as ultimately modulating plant growth. Phytohormones in biofertilizers, especially cytokinins, could help to drive plant growth under enough water, light and mineral nutrients through progressing faster by the various cell cycle checkpoints leading to the production of more cells. Soil plant growth promoting rhizobacteria (PGPR) are also able to promote plant growth through various mechanisms (such as nitrogen fixation, phosphorus and zinc solubilization). The principal mechanism for some mineral solubilization like phosphorus can be performed through the production of organic acids, and acid phosphatases play a major role in the mineralization of organic phosphorous in soil (Bhardwaj et al. 2014). Therefore, phosphate solubilizing soil microorganisms play some part in correcting phosphorous deficiency of plants. It could be concluded some mechanisms of biofertilizers as follows:

(1) Microorganisms that incorporate nitrogen into the plant-soil system through biological nitrogen fixation like *Mesorhizobium*, *Bradyrhizobium, Azorhizobium* and *Allorhizobium*,

(2) Microorganisms that increase nutrient and water uptake like mycorrhizae, and *Azospirillum* spp.,

(3) Microorganisms that increase the availability of nutrients found in the soil in not assimilable forms like *Bacillus megaterium*or *Pseudomonas fluorescens Pseudomonas*, *Bacillus* and *Flavobacterium Bacillus, Pseudomonas,* and *Clostridium* and fungi such as *Aspergillus, Penicillium* and *Mucor*,

(4) Microorganisms that possess antagonistic activities against plant pathogens like *Pseudomonas, Bacillus, Serratia, Flavomonas, Curtobacterium* and *Trichoderma*.

*Nanofertilizer mechanisms*

It is found that, large amounts of fertilizer in form of ammonium salts, nitrate and urea or phosphate compounds may be harmful under certain conditions. The over-application of fertilizers may be undesirable for plants because of the loss of these nutrients as run-off causing environmental pollution (Wilson et al. 2008). Nanomaterials usually have potential contributions in slow release of fertilizers. Furthermore, nano-coatings or surface coatings of nanomaterials on fertilizer particles hold the material more strongly from the plant due to higher surface tension than conventional surfaces (Solanki et al. 2015; Subramanian et al. 2015). Moreover, nano-coatings provide surface protection for larger particles (Brady and Weil 1999). Fertilizers with sulfur nano-coating ($\leq$ 100 nm) are useful with slow release fertilizers as the sulfur contents are beneficial especially for sulfur deficient soils

(Brady and Weil 1999). The stability of the coating reduced the rate of dissolution of the fertilizer and allowed slow sustained release of sulfur coated fertilizer (Subramanian et al. 2015; Manjunatha et al. 2016; Subramanian and Thirunavukkarasu 2017). In addition to sulfur nano-coatings or encapsulation of phosphate and urea as well as their release will be beneficial to meet the soil and crop demands (Solanki et al. 2015; Belal and El-Ramady 2016; Khan and Rizvi 2017).

Nanotechnology use in nano-fertilizer has offered a new technique in improving existing crop management (Ditta et al. 2015; El-Ramady et al. 2017, 2018). Concerning the mechanism for nano-fertilizer, it mainly depends on the nano-active ingredients (1–100 nm in diameter and have a large specific surface area), which can result in an acceptable reactivity increasing the effective absorption of nutritional elements and essential compounds for plant growth and metabolism (Morteza et al. 2013). In nano-fertilizers, nutrients can be encapsulated by nanomaterials, coated with a thin protective film, or delivered as emulsions or nanoparticles (Chhipa 2017). In a new type of nano-fertilizers, the nutrients can be released in response to environmental factors. It seems that nanofertilizers could be able to release nutritional elements in a controlled manner (slowly or quickly) in reaction to different environmental fluctuations such as soil acidity, moisture and temperature, so it can enhance plant growth more effectively compared with traditional fertilizers. Consequently, it is essential to reduce nutrient losses in fertilization and to increase nutrient use efficiency through the application of the smart nano-fertilizers (Siddiqui et al. 2015). Nutrients are absorbed by plant root or leaves; nanofertilizers are absorbed by both organs due to their gradual and controlled releasing. So, nano-fertilizers are preferred to other fertilizer types. The application of nano-fertilizers is most effective in comparison with common fertilizers due to more efficient absorption by plants and fast releasing (Solanki et al. 2015; Belal and El-Ramady 2016; Khan and Rizvi 2017).

Nanostructured formulation through mechanisms such as slow/controlled release or targeted delivery mechanisms and conditional release, might release their active ingredients in responding to environmental triggers and biological demands more precisely (Manjunatha et al. 2016). The use of nanofertilizers may(1) reduce soil toxicity,(2) increase nutrients use efficiency, (3) minimize the potential negative effects associated with over dosage and (4) reduce the frequency of the application. Hence, nanotechnology has a high potential for achieving sustainable agriculture, especially in developing countries (Mani and Mondal 2016). In fact, nano-fertilizers have opened up new opportunities to improve inputs use efficiency, minimize costs and environmental deterioration. Therefore, the scope for application of nanofertilizers in agricultural system needs to be prioritized in 21$^{st}$ century to accelerate the productivity of crops and sustains the soil health and environmental quality through promoting use of nanoparticles in fertilizers and pesticides as well as nanosensors in soil microbial activity (Belal and El-Ramady 2016; Chhipa 2017; Sarlak and Taherifar2017).

Therefore, it could be concluded that, some similar sides could be noticed regarding the synthesis of both bio- and nano-fertilizers especially the role of microorganisms in the biosynthesis. Many species or strains of microbes have been used in production of these biological fertilizers under different mechanisms.

*Fate and behavior of biological fertilizers in agroecosystems*

The fate and behavior of biological fertilizers (nano- and biofertilizers) in different agroecosystems considered one of the most important issues in the environmental sciences. Due to their effects on agroecosystems, negative and positive effects should be evaluated in different agroecosystem compartments including soil, water, crop or plant and microorganisms as well as human and animals (Belal and El-Ramady 2016; Shalaby et al. 2016; Lu et al. 2017; Sheng and Liu 2017). In general, there are common benefits could be summarized resulted from the application of biofertilizers and biologically mediated- nanofertilizers including (1) improving and sustaining the soil fertility, (2) reducing the environmental pollution through reduced use of chemical fertilizers, (3) increasing the ability of plants to uptake water and nutrients from the soils, (4) reducing the demand of irrigation and fertilization doses for crops, and (5) increasing the quantity and quality of crop yields in both, field and greenhouse conditions. On the other hand, the negative side for these fertilizers should be predicted and evaluated in the foreseeable future (Thul and Sarangi 2015). The physicochemical properties of soils could be indicated that, the specific soil properties must be an important consideration in the assessment of the fate and transport of engineered nanoparticles in the environment.

*Nano- and bio-fertilizers in soils*

It is well known that, soil is the main source for supporting cultivated plants with essential nutrients and water as well as the critical functions of numerous terrestrial life forms. It is really a finite and non-renewable resource and its microbes are very essential for different biogeochemical cycles of nutrients (i.e., C, N, S, P, etc.)and other minerals in soils (Sathya et al. 2016). This soil could be considered as ecosystem includes abiotic components (water, air, minerals and organic matter) in complete interaction with biotic components (macro- and micro-organisms). These components are the main dominant controlling the sustainability of this soil ecosystem through maintaining soil fertility, plant productivity and soil health (Seneviratne et al. 2017). It could be noticed that, several micro-organisms are beneficial microbial isolates in the form of bioinoculants including bio- and nano-fertilizers, biocontrol agents, and organic decomposers. These microbes could provide plants with necessary nutrients and excrete many growth-promoting compounds as well as provide resistance to a variety of diseases. It is worth to mention that, the rhizosphere is crucial for the bio- and nano-fertilizers. This rhizosphere totally effects on fate and behavior of the bio- and nano-fertilizers from one side and also influences with the characterization of both bio- and nano-fertilizers from the other side. That means bio- and nano-fertilizers effect on the rhizosphere including the beneficial sides (plant nutrition, protection, crop productivity) and the harmful effects (through risks on non-target microbes and others in soils) on the biological status of this rhizosphere (Bhardwaj et al. 2014; Thul and Sarangi 2015; Dwivedi et al. 2016). The effects of bio- and nano-fertilizers on soils include microbial community diversity, soil nutritional status and its fertility, and crop productivity. Therefore,the effectiveness of both biologically mediated nanofertilizers and biofertilizers mainly depend on the surrounding agro-environment.

The interaction between nanoparticles and different environmental compartments including microorganism, plants and soil have been extensively investigated (Dwivedi et al. 2016; Karimi and Fard2017; Terekhova et al. 2017). Therefore, the fate, transport, bioavailability and phytotoxicity of nanofertilizers in soils mainly depend on the physico-chemical properties of soil (Benoit et al. 2013; Dwivedi et al. 2016). These soil properties include different physical (e.g., soil texture or clay content), chemical (e.g., soil pH, salinity, cation exchange capacity) and biological properties (e.g., soil organic matter, soil microbial community and activity). The common reactions for nanofertilizers in soils include aggregation/ agglomeration, dissolution to the ionic metal, transport, mobility, uptake and sorption of nanoparticles in the soil (Dwivedi et al. 2016; Zhang et al. 2017a). On the other hand, physico-chemical properties of nanoparticles including shape, size and surface charge, which control the agglomeration, dissolution and aggregation of nanoparticles into soils. Therefore, soil characteristics should be considered an important factor controlling the soil transport, distribution, fractionation and subsequent bioavailability of nano-particles (or nano-fertilizers) to plants.

Concerning the biofertilizers and its fate in soils, as mentioned before, the microbial inoculants are influenced by soil characteristics, the inoculant properties and the environment. Although several microbial inoculants have been widely adapted for many crops, the beneficial effects of these inoculants still not consistently applied. Great threats effect on the survival and establishment of these organisms in rhizosphere representing in the changing environments or different environmental stresses including salinity, drought, and extreme events. Therefore, several interactions may happen to biofertilizers in soils affecting the efficiency of them. On the other hand, there are several microbial communities (like halo-tolerant bacteria) in the rhizosphere could contribute to the ability of some plant species and surviving under extreme environments (Suyal et al. 2016). It is worth mentioning that, in last few years the majority of bio-fertilizers or bio-inoculants used are mostly *Rhizobia*, constituting about 79 % of the global demand, where phosphate-mobilizing bioinoculants represent about 15 %, with other bio-inoculants, such as mycorrhizal products, making up 7 % (Suyal et al. 2016). Apart from the beneficial effects of biofertilizers on soils, there are several problems or harmful effects may result from the interaction between microbes of biofertilizers and soil microbes such as the stimulating soil-borne pathogens, producing phytotoxic substances, inhibiting plant growth and development and immobilizing plant nutrients.

*Nano- and bio-fertilizers in agroecosystems*

The main target for the agricultural sector nowadays is how to produce safe and enough foods with sustaining it. It could be sustained in this sector through the sustainability of different agroecosystems. The sustainability of this agroecosystem is totally controlled by the functional balance between both the productivity of plants and the processes of soils (nutrient recycling, soil microbial activity, soil organic decomposition, etc). No doubt that soil microbes have the magic key in creating a complex network for the microbial interactions with agroecosystem or plants and soil components (Seneviratne et al. 2017).This network is completely governed by several microbial and plant signals playing a great role in the communication within agroecosystems. Therefore, several interactions in agroecosystems should be studied including plant–microbe interactions (Choudhary et al. 2016; Seneviratneet al. 2017; Vergani et al. 2017), soil-microbe interactions (Panda et al. 2015; Malik et al. 2017), soil-plant interactions (Yao and Zhu 2015; Loh et al. 2017), plant-microbe-soil interactions (Yao and Zhu 2015; Miki and Doi 2016; Vimal et al. 2017), etc.

Concerning the effects of nanofertilizers on agroecosystems, several investigations should be conducted to follow and monitor the fate, behavior and biosafety of these nanofertilizers on the ecosystems including plants, soils, water, microbes, etc. It is found that, different concentrations of some nanoparticles (like $TiO_2$ and ZnO) decreased the diversity of soil bacteria after 60 days incubation (Karimi and Fard2017). On the other hand, nanofertilizers should interact with soil components including soil microbes without any toxic effects and these nanofertilizers should be applied in a proper form and amount. The expected effect of nanofertilizers on beneficial soil microbes including N-fixing bacteria, nitrifying bacteria, arbuscular mycorrhizal fungi or plant growth-promoting rhizobacteria still need more investigations (Karimi and Fard2017; Terekhova et al. 2017). Regarding soil enzyme activities including intracellular or extracellular (found in both soil solution and bound to soil components), they also need more studies and monitoring the effects of nanofertilizers on them. Many publications have been focused on the nature and manufacturing of nanofertilizers as well as different effects of these nanomaterials on plant and its productivity (Khan and Rizvi2017; Sarlak and Taherifar2017) but a few reported on soils and their dynamics in soils (e.g., Chhipa 2017; Subramanian and Thirunavukkarasu 2017). More researches are needed in order to evaluate the release nutrients from nanofertilizers commensurate with different crop demands.

Regarding different effects of biofertilizers on agroecosystems, there are direct and indirect effects including increasing the crop productivity (as a direct response) and inhibition of phyto-pathogens by several biocontrol mechanisms like phyto-hormones synthesis, preventing plant diseases and accelerating the uptake of some soil nutrients (Shaikh et al. 2016). It is worth to mention that, a strong competition between soil microbes and different strains in biofertilizer could be hinted and more information regarding this competition is needed. Although great efforts have been evaluated concerning these previous interrelationships and their impact on biofertilizers efficacy, more investigations should be conducted on both the short- and long-term using different common methods like the analysis of soil microbial activity, soil microbial biomass, soil microbial community structure and diversity (O'Callaghan 2016; Malusà et al. 2016). Therefore, it could be concluded that, bio- and nano-fertilizers have complicated interactions in agro-ecosystems and these interactions include direct and indirect mechanisms.

*Biological effects of nano- and bio-fertilizers on plants*

*Application methods*

Rhizosphere is the surrounding area for plant roots, which the soil, plant roots, microbes and fauna strongly interact. This space is further classified into ecto-rhizosphere(the portion outside the root) and endorhizosphere (the root epidermis and cortex), where endophytic microorganisms can be present(Haldar and Sengupta 2015). Soil application method might be more convenient for the farmer because of less time required, but generally a higher amount of inoculant is then needed. Soil inoculation may be done either with liquid or solid formulations. In the factory, the inoculum normally is mixed with the inert material, but it could be mixed by the farmer prior to application, especially when liquid formulations are used (Malusá et al. 2012; O'Callaghan 2016). Phosphorus -solubilizing microorganisms might also be considered a method for increasing the availability of nutrients (in particular phosphorus) to plants and eventually affects the tolerance of the plant to soil pathogens. The application methods of biofertilizers depend on the kind of crop concerned (weather annual crops or tree crops). Biofertilizers might be inoculated for annual crops by broadcasting the inoculum over the soil surface, alone or together with seeds, or by in-furrow application, seed dressing, or coating. In case of tree crops, biofertilizers might be initially inoculated by root dipping or seedling inoculation (Muresu et al. 2003).

The application method in the field depends on the kind of crop concerned. In case of the annual crops, the biofertilizers could be broadcasted by in-furrow application, or over the soil surface, alone or when sowing the seeds. These biofertilizers could be also applied by directly treating the seeds with (1) dusting or mixing the biofertilizer with dry seeds, (2) slurry or mixing the biofertilizer with wetted seeds, or suspended in water and (3) coating or suspending the biofertilizer to prepare a slurry, mixing with the seeds, where the biofertilizers are coated by mixing them with a fine powder of inorganic inert materials (e.g.,clay, charcoal, ground lime, rock phosphate, dolomite, calcium carbonate or talc). Moreover, the microbial populations in the soil may dilute or counteract the effects of introduced biofertilizers. It is reported that, the inoculated strains in the soil or on root rhizosphere have been effective for 30–40 days after inoculation (Bashan et al. 1995, 2014). Therefore, it should be repeated application of biofertilizers during the growing season, with an interval of 2–4 weeks, increase the effectiveness (Malusá et al. 2012, 2016).

Concerning methods of the nanofertilizer application, there are three main methods including (1) spray or foliar application (nano-formulations of micronutrients may be used as crop sprays for enhanced foliar uptake (Duhan et al. 2017). (2) Soaking method, where soaking of cotton seeds in nanofertilizers produced favorable effects and reduced the amount of fertilizers applied by half (Vakhrouchevand Golubchikov 2007). (3) Soil application, where the soil application (like 30ppm Cu-NPs) may increase yield of wheat crop significantly to match the food demand of growing population (Abdul Hafeez et al. 2015).

Therefore, the main methods for the application of nano- and bio-fertilizers include soil and foliar application as well as the soaking method. The best method depends on the cultivation method as well as the characterization of fertilizer.

*Uptake, translocation, accumulation and phytotoxicity by plants*

It is well documented that, nanotechnology already has several applications including biomedicines, targeted drug delivery, cancer therapy, cosmetic industries, electronics and biosensors, as well as waste water treatment, targeted pesticides and fertilizer delivery (Tripathi et al. 2017). It is estimated that, global investments in the field of nanotechnology have been increased worldwide to reach about $10 billion and $1 trillion in 2005 and 2015, respectively (Tripathi et al. 2017). As mentioned before, manufactured nanoparticles could reach to different environmental compartments including soils, water, air, and plants through the handling or the accidental processes (Cornelis et al. 2014; Aziz et al. 2015; Prasad et al. 2016). The main and final sink for these nanoparticles is demonstrated to be the soil (Cornelis et al. 2014), whereas the second is considered to be the air. Undersoil conditions, these nanoparticles may be toxic to soil organisms and cultivated plants, several nanoparticles could be transported and uptake by plants causing the phytotoxicity (Tripathi et al. 2017).

Several studies have been demonstrated that, many nanoparticles may cause the phytotoxicity through the production of reactive oxygen species resulting, thereby, an oxidative stress, proteins and DNA damage, lipid peroxidation in plants as well (e.g., Siddiqui et al. 2015; Watson et al. 2015; Rao and Shekhawat 2016; Tripathi et al. 2016; Tassi et al. 2017; Tripathi et al. 2017). Many investigations also have been published regarding the uptake and translocation of nanoparticles within plants as well as the accumulation in aerial parts of plants (Jośko et al. 2017; Siddiqi and Husen 2017b; Tripathi et al. 2017; Zhang et al. 2017b; Ma et al. 2018). Furthermore, some distinguished features could be hinted after the accumulation of nanoparticles in plants including (1) general damage for different parts of plant, (2) degradation of crop quality, (3) decrease the germination rate of seeds, (4) decrease biomass weight and length of roots and shoots, (5)alter the process of photosynthesis, (6) reduce the rate of transpiration, (7) enhance lipid peroxidation, (8) increase the damage of DNA, (9) and genotoxicity of plants (Tripathi et al. 2017). It could notice that, plants definitely possess inherently some defense strategies to overcome this nano-toxicity through activating many enzymatic and non-enzymatic defense systems (Hossain et al. 2016; Shukla et al. 2016; Tripathi et al. 2017). Nanoparticles may be accumulated in plant cells and transported by apoplast or symplast through plasmodesmata. However, the exact mechanisms by which plants take up or uptake these nanoparticles at biochemical, physiological and molecular levels are still unknown and remain to be explored (Shukla et al. 2016; Rizwan et al. 2017). The uptake, bioaccumulation, biotransformation, and risks of nanomaterials for food crops are still not well understood. Very few nanomaterials and plant species have been studied mainly at the very early growth stages of the plants (Tripathi et al. 2017).

On the other hand, nanofertilizers may have the ability to deliver and save the essential nutrient for plant nutrition but under certain conditions according to the soil and fertilizer characterizations. Therefore, the uptake, translocate and phytotoxicity of nanofertilizers will be controlled with several factors, as mentioned before. It is reported that, nutrients could be released from nanofertilizers to be available for plant uptake for a long time (for more than 50 days for nitrate nitrogen as slow release nanofertilizers) comparing with conventional fertilizer like urea (Subramanian and SharmilaRahale 2009). Concerning the biofertilizers and its uptake by plants, these microbial inoculants, as well known, have main target representing in delivering nutrients to the soil and plants. These biofertilizers also could convert nutrients from unavailable to available forms as well as the microbial populations are responsible for supplying the soluble nutrients to the plants (Bhardwaj et al. 2014; Wong et al. 2015; Tomer et al. 2016; Mahanty et al. 2017). Therefore, there are indirect and direct factors controlling the nutrients from both bio- and nano-fertilizers. The most common similar item gathers between biofertilizers and biological mediated nanofertilizers is the beneficial roles of certain microbes (Table 2). Therefore, it could be concluded that, soil microbes have crucial effects due to the interaction with plant roots in the rhizosphere. These interactions include the direct effects (enhancement the bioavailability of

**TABLE 2. The combined features for bio- and nano-mediated biological fertilizers comparing with the conventional fertilizers**

| General items | Nano- and bio-fertilizer |
|---|---|
| The definition | Biofertilizer are live or inert microbes; biological nanofertilizers may be produced by microbes |
| The conventional fertilizers | Emerging alternatives for chemical fertilizers |
| Eutrophication | May be eliminated or reduced |
| Soil and water pollution | May be eliminated or reduced |
| The nutrient use efficiency | Very high due to increase plant bioavailability (**70%**) |
| Environmental protection | They could enhance it |
| Effective duration of nutrients release into rhizosphere | Excellent alternatives to soluble fertilizers and may continue in rhizosphere to about **30 days** |
| The sustainable agriculture | Could be achieved by improving energy, economy and environment |
| Loss rate of nutrients from fertilizer | They can reduce loss rate of nutrients from fertilizer into soil by leaching and/or leaking |
| Application of agrochemicals and their residues in soils | They could protect and improve crop production without residual effects in agroecosystems |
| Postharvest management | They could promote postharvest of crops |
| Precision farming | They could be used in this agro-system |
| Quality and quantity of crop | They could improve crop quantity and quality |
| Susceptibility to plant diseases | They have the ability to control plant diseases |

nutrients in the rhizosphere) and indirect through promoting uptake efficiency of nutrients *via* the promotion of plant root growth.

*Beneficial effects of nano- and bio-fertilizers*

As mentioned before, chemical fertilizers may have some problems including leaching out, polluting water basins, destroying microorganisms and friendly insects, making the crop more susceptible to the attack of diseases, reducing the soil fertility and thus causing irreparable damage to the overall system; however, it seems that biofertilizer application can overcome these problems. Today, biofertilizers have emerged as a highly potent alternative to chemical fertilizers due to their eco-friendly, easy to apply, non-toxic and cost effective nature. Also, they make nutrients that are naturally abundant in soil or atmosphere, usable for plants and act as supplements to agrochemicals (Bhardwaj et al. 2014; Mazid and Khan 2014; Wong et al. 2015; Malusà et al. 2016; Mahanty et al. 2017). Biofertilizers have also emerged as potential environment friendly inputs that are supplemented for proper plant growth. They hold vast potential in meeting plant nutrient requirements while minimizing the use of chemical fertilizers. It could be improved plant growth and its yield using the bio-inoculants. These bio-inputs or bio-inoculants are commercial products containing living cells of different types of microorganisms. These microorganisms have the ability to convert and mobilize nutrients from unavailable form to usable form in rhizosphere (Malusà et al. 2012; Malusá and Vassilev 2014). Safely convert organic matter into simple compounds that provide plant nutrition, improve soil fertility, maintain the natural habitat of the soil and increase crop yield (Malusà et al. 2016; Mahanty et al. 2017).

Biofertilizers have a positive effect on growth, yield and yield components for many crops. It is reported that, plant growth promoting microorganisms can be successfully used as complementary tools to organic and chemical fertilization for improving plant nutrition(Malusà et al. 2016). It is clear that, the confidence of the studies conducted under field conditions will largely depend not only on our knowledge of the nutrient and biological charge of the soil and composts or manures employed as organic fertilizers, and the growth promoter activities of the microorganisms employed as biofertilizers, but also on their particular interactions. This knowledge will be instrumental in the implementation of successful, low-environmental impact and more profitable agriculture production systems (organic or conventional). It could be concluded the common benefits of using biofertilizers in agriculture as follows:

(1) Increase the ability of plants to uptake water and nutrients from the soil,
(2) Reduce the dose demand for irrigation and fertilization for cultivated crops,
(3) Increase the growth and seedling establishment,
(4) Increase the rooting of cuttings,
(5) Increase the vigor of seedlings and adult plants,
(6) Enhancement the biocontrol of pathogens,
(7) Reduce the time of harvest and promote the postharvest of crops,
(8) Increase crop yields as well as weight and quality of fruits under both field and greenhouse conditions,
(9) Compatibility with organic production of agricultural crops,
(10) Reduction of environmental pollution through reduced use of pesticides and chemical fertilizers and
(11) Bioremediation of soils contaminated with petroleum derivatives and heavy metals.

It is worth to mention that, the combined application of these biofertilizers had more efficiency because of some positive interaction between their microorganisms in soil that results to synergistic effect as well as increase in yield components and thereby in final grain yield(Ajirloo et al. 2015). There is a need for more understanding of the role of root–associated with microbes in the nutrition and/or yield of agricultural crops. Furthermore, the role of biofertilizers is also needed in the agricultural production as supplements or alternatives to organic or mineral fertilizers (Simarmata et al. 2017).

Nanotechnology is becoming increasingly important for the agricultural sector. Therefore, agricultural technology should take advantage of the powerful tools of nanotechnology for the benefit of mankind. These tools of nanotechnology could be employed to address the urgent issues of environmental pollution and its protection. Nanotechnology could provide the society with the proper technologies, which it could be used in environmental detection, sensing and remediation (Hao et al. 2015; El-Ramady et al. 2017; Yadav et al. 2017). Nanofertilizers are innovative agricultural inputs which are aimed to release nutrients into the soils gradually and in a controlled way, thereby avoiding environmental damages and improving the crop growth and productivity (Singh and Prasad 2016; Chhipa2017; Subramanian and Thirunavukkarasu2017). As mentioned before, nanofertilizers could be considered nano-structured formulations, which have the ability to deliver or control the release of active ingredients or through slow/controlled release nutrients in response to environmental triggers and biological demands in more precise manner (Solanki et al. 2015). Therefore, it could be concluded the benefits of using nanofertilizers in agriculture as follows:

(1) Nano-formulations of agrochemicals for applying pesticides and fertilizers for crop improvement and plant nutrition,
(2) The application of nanosensors/nanobiosensors in crop protection for the identification of diseases and residues of agrochemicals,
(3) Nano-devices for the genetic manipulation of plants,
(4) Plant disease diagnostics,
(5) Animal health, animal breeding, poultry production,
(6) Postharvest management,
(7) Increase the efficiency and food quality due to accelerated absorption,
(8) Prevention the loss rate of fertilizers by leaching and complete uptake by plants due to availability and controlled release in the growth period,
(9) Reduction in soil and water pollution and consequently food products through reduction of fertilizer leaching, and
(10) Increase nutrients use efficiency, reduce soil toxicity, and minimizes the potential negative effects associated with different over dosages (Solanki et al. 2015; Belal and El-Ramady 2016; Chhipa and Joshi 2016; Chhipa2017; Khan and Rizvi 2017; Subramanian and Thirunavukkarasu 2017).

In Egypt, great efforts have been achieved in the production of biological fertilizers but there is still more efforts should be done in the future. There are some commercial biological fertilizers could be found in the Egypt market nowadays and some still

**TABLE 3. Some commercial products of biofertilizers and nano-fertilizers by soil, water and environment research institute (SWERI), Egypt**

| Name | Interaction | Family plants | Role | Formula |
|---|---|---|---|---|
| I. Biofertilizers | | | | |
| **Okadin** | Symbiotic | Legumes | $N_2$- fixation | Powder |
| **SWERI** | Non-symbiotic | Cereals and other | $N_2$- fixation | Powder |
| **SWERI (NPK)** | Non-symbiotic | Cereals and other | $N_2$- fixation, P and K solubilizers | Powder |
| **Cyanobacteria** | Non-symbiotic | Cereals and other | $N_2$- fixation | Powder |
| **Mycorrhizal** | Symbiotic | Legumes, cereals and other | P- solubilizers | Powder |
| **Nemaless** | Non-symbiotic | Horticulture plants and others | Bio-control | Liquid |
| **Compost tea** | Non-symbiotic | General | Plant nutrition | Liquid |

II. Nano -fertilizers*

| Name | Method production | Formula | Role |
|---|---|---|---|
| **Nano-Se** | Biological | Liquid | Mitigation of the different stress i.e. salinity, drought, heat…etc. |
| **Nano-Si** | Biological | Liquid | Plant nutrition and control from insects |
| **Nano-Cu** | Biological | Liquid | Plant nutrition and control from plant diseases |

*all nano-fertilizers use in empirical and under research in the empirical stage as presented in Table 3.

## Conclusion

From the above mentioned, it could be concluded that, the importance of biotechnology and nanotechnology applications in the production of bio- and nano-fertilizers, which represents modern ways can be developed to serve the humanity in the near future. It should increase the agricultural production to comply with the rapid increase in human populations so that it can cope with food shortages and degradation of agricultural land, climate changes and many of the difficulties that we face in this period of time. In this review, it could observe many similarities between bio- and nanofertilizers especially in the importance of the soil, plants and preservation of the environment and these similarities are almost identical. Both of them represents an alternative to traditional fertilizers, which increases the absorption of nutrients, reduces lost nutrients comparing with traditional methods, improves plant growth and its productivity, increases bearing plant external stress, resistant to plant diseases, improves soil properties, reduce soil degradation and raising soil fertility. On the other hand, there are some differences in specific points, such as mechanisms of each other in the soil and plant, the effective rates, their benefits to the soil and plants as well as their role in preserving the environment.

However, it could note that the nanoparticles as well as micro-organisms present in the environment in multiple ways and frequently without human intervention. Some are useful and others harmful. What scientists do is careful selection of species of organisms that are useful as well as scrutiny of the methods of manufacturing nanoparticles. Also, improve application methods and rates, access to optimal concentrations in the addendum in order to improve soil properties and increase agricultural production with attention to the environmental aspects. It was observed that, what distinguishes the nanoparticles is less than 100 nanometers in size, and by extension the large specific surface which gives it its importance in the ease of movement within the soil and plants. Consequently, contribute to all the vital operations of the plant and the result is increased productivity and quality attributes of the soil and plants. The inoculation of microbial organisms characterized as produce hormones and antioxidants, as well as to their importance in the nitrogen fixation, the validity of some macro- and micro-nutrients, its importance in the decomposition of organic materials and being the most important factors in mineralization and converted from organic materials to inorganic, which facilitates its movement in the soils and absorbed plants. Multiple methods used to obtain nanoparticles, including physical, chemical and biological. However, the biological method for the production of nanoparticles is the safest way to increase agricultural production with preserving the environment. Therefore, science is still doing a lot for the detection of many other ways not yet used. To get a lot of material and multiple types of living organisms of all kinds, research should be depended on nano- and bio-technology. The field is still open for researchers to gain access to what serves humanity. Although the methods used are great, however, the researchers are always looking for the better.

When organisms exist either in nature or add as bio-fertilizer, they are capable of turning a large part of the elements of the case of nanoparticles. Hence, the importance of living organisms in the soils also comes from their ability to transform the elements of the case nanoparticles. So, it might be added to the importance of soil organisms being produced nanoparticles. Hence, it may add the interpretation of the results obtained by bio-fertilizer when the soil microbial inoculation or seeds, and estimating nanoparticles associated with it in the soil. Here, open secret of organisms that did not declare fully its secrets yet and give researchers a new way of thinking about how to deal with it. Finally, because the topic is very interesting and attract many researchers to work it and discover its secrets, there is still a lot of effort should be made in the study of bio- and nano-fertilizers in terms of their behavior and their impact on the environment as well as their interactions.

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