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# Nano fertilizer is boon for Soil Health

***Gayatri Divekar[1], Sharda Dagade-Gadale[2], Asha Desai3, Shobha Waghmode[3*]***

***1- National Institute of Virology, Pune 411021.***
***2-Department of Chemistry, Y.M.College, Bharati Vidyapeeth, Pune-411038.***
***3-Department of Chemistry, MES Abasaheb Garware College, Karve Road, Pune- 02, Maharashtra- 411004, India***

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***Corresponding E-mail:**
*shobhawaghmode@gmail.com*

**ABSTRACT**

Nanoparticles are being increasingly used in the agriculture sector as opposed to conventional fertilizers. As it can be observed from the results, the nanofertilizers used are quite beneficial for plant growth. Biosynthesis of nanoparticles can be the cheaper method of production since the technology for large scale growth of bacteria and simple eukaryotes like yeasts is already well stabli shed.

Though research on nanofertilizers has been ongoing for the past two decades its application is comparatively less. If applied successfully on a larger scale, nanofertilizers offer great benefits to crop production and at the same time do not pollute the environment.

## 1. INTRODUCTION -

Nanotechnology, is the concept of manipulating material on the nanoscale causing significant changes in its properties. This technology has been used in various sectors such as automobile, electronics, IT, pharmaceutical, medical and cosmetic sectors(WHO meeting) In the past two decades advent of nanotechnology is being seen in the agriculture sector, especially in terms of precision agriculture(Duhan *et al.*,2017) . Precision agriculture basically implies the use of technology for making precise decisions which help in improvement of crop quality and yield. In this aspect, nanofertilizers and nanopesticides are being used. This review will concentrate on application of nanofertilizers in modern agriculture.

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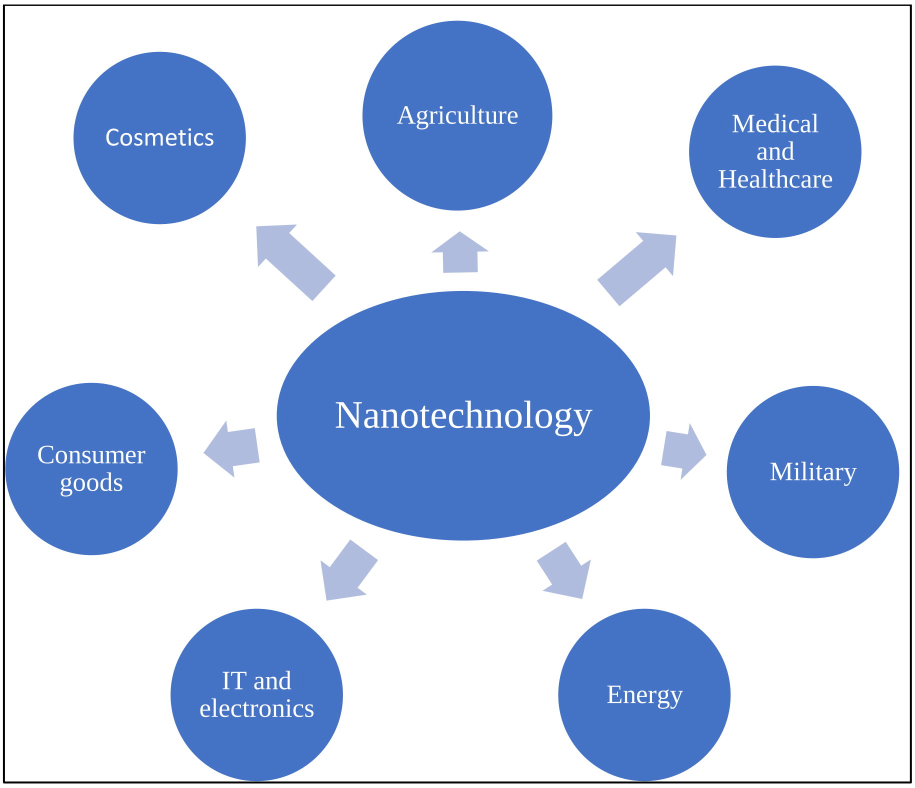


**Figure 1: Uses of nanotechnology**

Nanoparticles are materials less than 100nm in size. Owing to their small size, they have a high surface area to volume ratio. This ratio indicates that a large amount of nutrients can be attached to a relatively small amount of nanoparticles. This exact concept is used in manufacturing of nanofertilizers.

Conventional fertilizers like chemical fertilizers have an adverse effect on the environment as well as low uptake of nutrients. Environmental pollution includes leaching, de-nitrification and volatilization of chemical fertilizers. Leaching may lead to eutrophication while nitrogen volatilization causes release of nitrous oxide in the air. This being a greenhouse gas, contributes to global warming("FAO/WHO expert meeting on the application of nanotechnologies in the food and agriculture sectors," n.d.)

Inversely nanofertilizers have a high efficiency of nutrient uptake and almost no effect on the environment as indicated by various studies.In nanofertilizers, nanoparticles are used as carriers for micronutrients like zinc, copper, manganese, iron and macronutrients like nitrogen, phosphorous, potassium, sulphur and calcium(Dimkpa and Bindraban, 2018).

Uptake of these nanoparticles varies among different plant species, but also depends on the chemical composition, function and size of the nanoparticles. A review by Rico *et al*(2011). shows the different pathways for uptake for different nanoparticles. This is shown in a concise manner in fig.(1). As

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can be observed from the figure, the data is still insufficient to form a proper conclusion about the uptake of nanoparticles by plants.

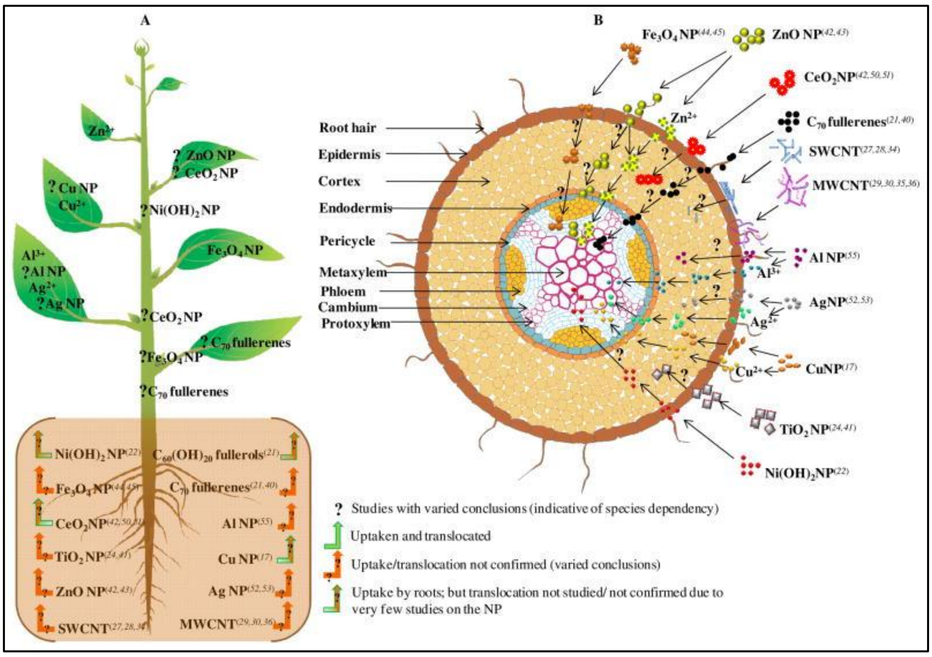


**Figure 2: Uptake, translocation and biotransformation of various nanoparticles in a plant (Rico *et al.*,2011)**

### 1.1 Toxicity –

A number of studies have been published regarding cytotoxicity of nanoparticles to plants as well as other ecological systems. As with toxicity studies, the result differs according to the conditions. It depends on the nanoparticle used, its quantity as well as the plant/s under study. Most of these studies show that nanoparticles used in proper amount and applied properly are not toxic to the plants and environment. This is seen from the fact that unlike conventional fertilizers, nanofertilizers do not volatilize and are almost completely absorbed by the plants various pathways as discussed above. However there are a few studies like the one by Wang *et al.*(2016) which shows that ZnO nanoparticles have a totally negative effect on *Arabidopsis* plants. Hence it is prudent to check toxicity of nanofertilizers before its large scale application.

## 2. MATERIALS AND METHODS –

Some of the most commonly used methods for synthesis and then characterization of nanoparticles used as nanofertilizers are stated in the following text.

### 2.1 Synthesis of Nanoparticles :

### a)Chemical methods of synthesis –

**Spray pyrolysis** : This is a simple method of nanoparticle synthesis which is cost effective and easy to perform*. In this technique, precursor solutions containing the desired nanoparticles are sprayed in the form of

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droplets on the hot surface of a furnace. This causes the solvent in the precursor solution to evaporate and leaves the nanoparticles in the vapour phase. A schematic representation of this process by Trakhtenberg *et al*. is shown in fig.(3)

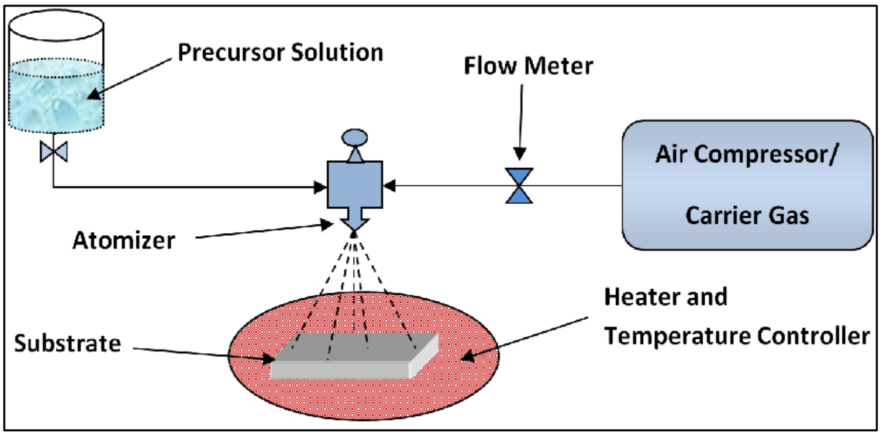


**Figure 3: Schematic sketch of chemical spray pyrolysis process(Trakhtenberg *et al.*, 2015)**

**Sol – gel method :**

This technique is a wet chemical process so its starting material is a solution or "sol". Through this process, the solution get gradually polymerized to form a gel like structure or colloid. Pawar *et al.*(2019) describes the use of sol-gel method for formation of titanium oxide nanoparticles. Here, they have used vacuum dry as final step for densification and formation of the nanoparticles. Advantage of this process is that it does not require expensive equipment and is relatively simple to perform.

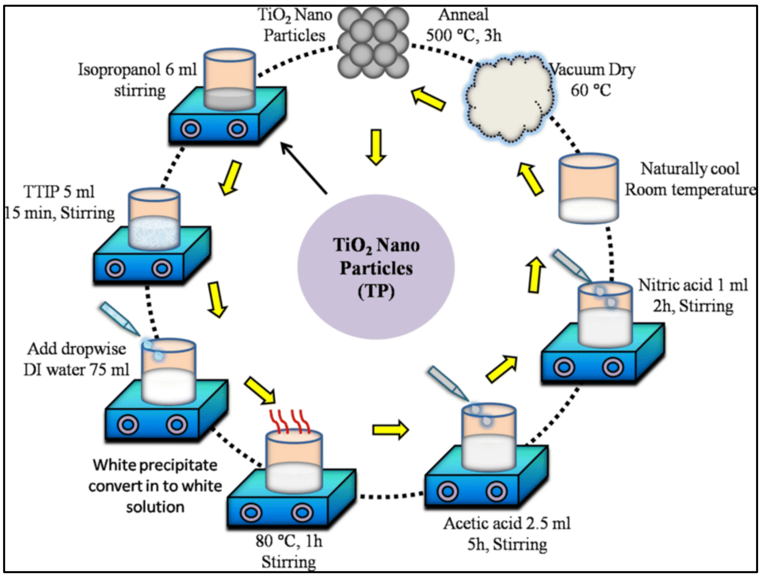

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**Figure 4: Sol-gel method (Pawar *et al.*)**

**Hydrothermal method :**

Hydrothermal method is commonly used to synthesize nanoparticles and is solution reaction-based method. This technique utilizes control of thermodynamic variables like temperature and pressure to form crystalline structures from solutions. The morphology and composition of the product nanoparticles depends on the settings of these variables along with the vapour pressure of the nanoparticles to be synthesized. There is minimum loss of materials when nanoparticles with high vapour pressure are produced by hydrothermal method (Gan *et al.*,2020).

**b)Biosynthesis –**

Biological systems like bacteria, fungi, algae and even viruses have been used for synthesis for metallic nanoparticles. The reason this method of synthesis is explored is to reduce the side effects of using chemically synthesised nanoparticles(Thakkar *et al.*,2009.).Studies have shown that silver nanoparticles are produced intracellularly/extracellularly by bacteria like *Pseudomonas stutzeri, Morganella sp.* and some *Lactobacillus* strains.* MKY3(yeast) and fungi like *Verticillum, Trichoderma asperellum* and *Aspergillus fumigatus* are also able to produce silver nanoparticles. Gold nanoparticles are produced when gold ions are supplied to extracts of plants such as *Cymbopogon flexuosus* and *Pelargonium graveolens.*

**2.2 Methods for characterization:**

**X-ray Diffraction –**

X-rays have a dual nature(particle/wave) and this is utilized in X-ray diffraction technique. This technique is based on the diffraction of x-rays by nanoparticles and the resulting diffraction pattern is measured by Bragg's law($n\lambda = 2d\sin\theta$). It helps in assessing the space between layers of atoms thus determining the crystal structure (Jose Chirayil *et al.*,2017) In X-ray diffraction technique, the sample is bombarded with a monochromatic beam of X-rays, which get reflected from the sample and are the detected by the detector (Patel and Parsania,2018).

This is an example of X-ray diffraction pattern obtained of ZnO nanoparticles. The peaks obtained determine that it is the hexagonal wurtzite phase of ZnO. No other peaks than that of ZnO indicate that the compound contains no impurities(Talam *et al.*,2012)

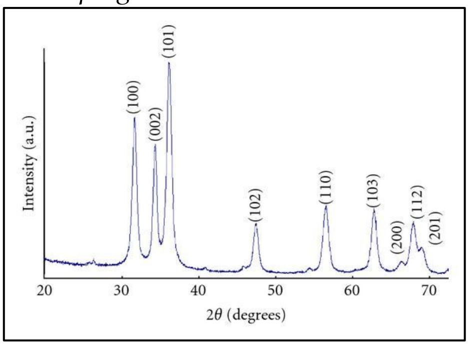


**Figure 5: XRD pattern of ZnO nanoparticles**

**FOURIER TRANSFORM INFRA-RED SPECTROSCOPY -**

In this technique, an infrared spectrum of emission or absorption of the nanoparticles is obtained. A molecule absorbs infrared frequencies equal to its vibrational frequencies. This absorbed energy gets amplified due to the vibrational motion of bonds of the molecule and is given out as radiation to form a spectrum. Fourier transform is the algorithm which converts the data obtained from the interferogram into an actual spectrum. Therefore this technique is used to characterize different elements as well as specific bonds in product nanoparticles(Baudot *et al*.,2010).

**SCANNING ELECTRON MICROSCOPY -**

This is a simple method for viewing actual structure as well as measuring the size of the product nanoparticle. In this technique, the sample is bombarded with a primary electron beam. After this beam collides with the sample, secondary electrons and backscatter electrons are created. These electrons are responsible for formation of SEM image(Vladár and Hodoroaba, 2020)

For characterization of the nanoparticle by SEM, the prepared sample should be of good quality; only then will the resulting image will be of high resolution and quality.

SEM image of hydroxy apatite nanoparticles by Kottegoda *et al.* used for characterization of HA nanofertilizer. As can be observed from the figure, the size of the nanoparticles ranges from approximately 17nm to 24nm.

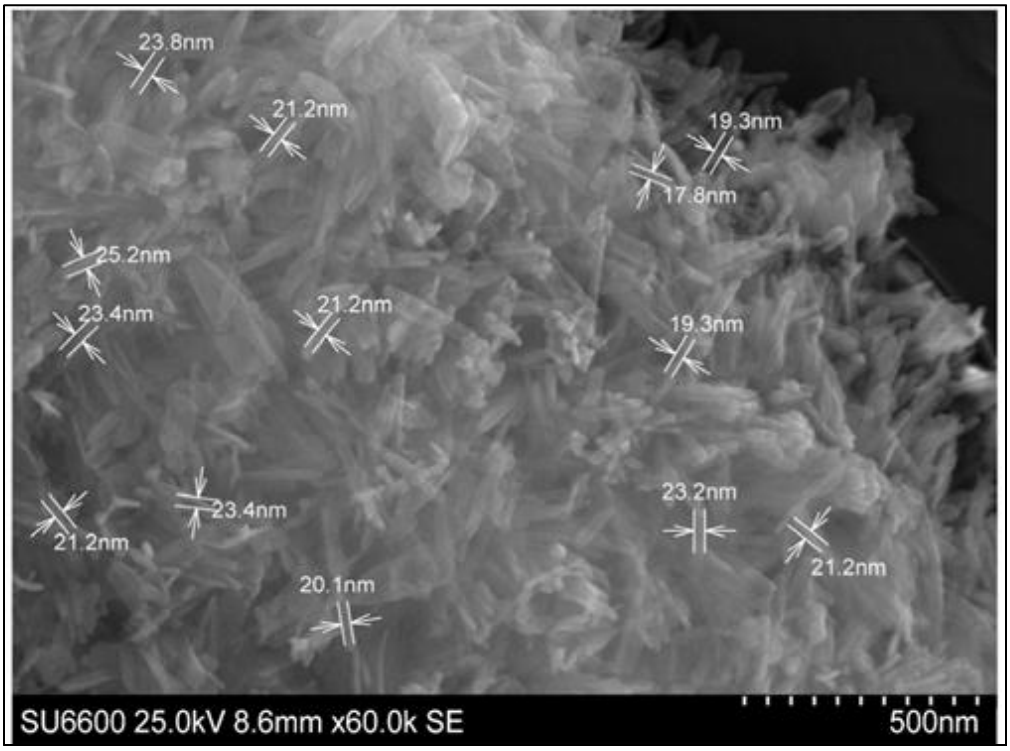


**Figure 6: Scanning electron microscope images of synthesized**

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(1) rgonium

(2) graveolen

(3) Pelargonium

(4) graveolen

**3. RESULT –**

Different nanoparticles used for various crops have been summarized in the following table. Some of these studies have shown the effect of nanofertilizers when supplied directly in the soil, or by foliar application or in an aqueous solution or tissue culture. Results obtained by hydroponic technique or tissue culture may vary when applied in soil on a larger scale, but they definitely give an idea about the usefulness of nanofertilizers.

| Reference | Crop | Nanofertilizers | Effects | Growth medium |
|---|---|---|---|---|
| Kottegoda *et al.*(2011) | No crop, only tested in soil | Urea modified hydroxyapatite nanoparticles encapsulated under pressure into cavities of the soft wood of *Gliricidia sepium.* | Slow and sustained release of nitrogen over time | Soil |
| Shebl *et al.*(2019) | *Cucurbita pepo* L | Zinc, Manganese and Iron nanooxides | Improved growth and yield | Soil |
| Jeyasubramanian *et al.*(2016) | Spinach | Iron oxide (Fe2O3) nanoparticles | Increased biomass production, stem and root lengths | Aqueous solution |
| Su *et al.*(2018) | Peanut | Carbon nanodots | Enhanced stress resistance | Soil |
| Khodakovskaya *et al.*(2012) | Tobacco cell culture | Multiwall carbon nanotubes | Increased growth of tobacco cell culture and upregulation of tobacco aquaporin gene | Tissue culture medium |
| Rangaraj *et al.*(2012) | *Zea mays* L. | Porous silica nanoparticles | Increased silica accumulation, leading to regulation of phyto compounds like phenol and proteins. | Soil |
| Shah & Belezerova(2009) | Lettuce seeds | Metal (Pd, Cu, Si, Au) nanoparticles | Increased shoot/root ratio | Soil |
| T. N. V. K. V. Prasad *et al.*(2012) | Peanut seeds | Zinc oxide(ZnO) nanoparticles | Increased germination, root& shoot growth. Increased pod yield | Soil |
| Mahajan *et al.*(2011) | *Vigna radiata, Cicer arietinum* | ZnO nanoparticles | Increased root and shoot growth at certain concentration | Agar |
| Salama *et al.*(2019) | *Phaseolus vulgaris* | ZnO nanoparticles | Increased concentration of | Soil |

| | | | | |
|---|---|---|---|---|
| | | | specific minerals in leaves. Increased amino acid and photosynthetic pigment content | |
| Rui *et al.*(2016) | *Arachis hypogaea* (peanut plant) | Fe2O3 nanoparticles | Increased total Fe content, biomass and chlorophyll content | Soil |
| Khodakovskaya *et al.*(2013) | Tomato plant | Carbon nanotubes | Twice the amount of flowers and fruits | Soil |
| Arora *et al.*(2012) | *Brassica juncea* | Gold nanoparticles | Increased growth and seed yield | Soil |
| Liu and Lal(2014) | *Glycine max* | Hydroxyapatite nanoparticles | Increased seed yield and biomass production | Soil |
| Suriyaprabha *et al.*(2012) | *Zea mays* L. | Porous silica nanoparticles | Increases concemtration of phytocompounds and silica accumulation in roots | Soil |

## 4. DISCUSSION –

Also the quantity used is less as compared to bulk fertilizers. It is observed from the toxicity studies that nanoparticles used in proper quantity are not harmful to the environment and hence can easily be used in regular agricultural practices.

Most of these applications are still in the initial stages and have not been used on a large scale. The reason for this may be the relatively higher cost of manufacturing and lesser availability. So it is imperative to find new techniques which will decrease the manufacturing costs, making it more readily available.

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