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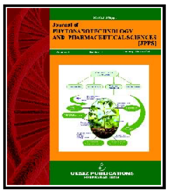

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The healthy and sustainable growth of medicinal and aromatic plants through nanotechnology

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Abstract

India is a land of agriculture with diverse climatic conditions. Therefore, domestication of the medicinal and aromatic plants (MAPs) from the forest zone through standardized cultivation practices is most essential. Good agricultural practices (GAP) as per standard guideline provide healthy growth of the plants with higher biomass yield. In spite of that, adaptation of any new technology in such cultivation boosts the yield synergistically. Nanoscience is such new technology by which many impossible domains became possible with easiest way. Of late, nanofertilization is such a new revolution in agriculture science, with that many states in India got their economic strength through effective cultivation of MAPs. Nanofertilization helps in improving nutrient uptakes by the plant roots, accumulate them in the plant body for many metabolic functioning, helps in sustain increase of plant growth and also leads to enhancement of higher amount of phytochemicals accumulation in plant body. In addition, reduced quantity of chemical spreads, reduced nutrient losses in fertilization, increased biomass yield through pest and nutrient management, *etc*., allow some resonant encumbrance of nano-technology to be implemented. Ultimately, the article highlighted the types of modern applications of nanofertilizers and its beneficial impact on MAPs in improved quality and efficiency of canopy yield and yield attributes.

1. Introduction

Nanotechnology is the study of the controlling the matter on an atomic and molecular scale. It is a very diverse concept and recently it is also used in medicine to cure many diseases. In 1964, Glenn T. Seaborg, Nobel Laureate in Chemistry, patented two of the elements, americium and curium. This was the beginning of patenting atomically and molecularly engineered matter. The term nanotechnology was coined in 1974 by Norio Tanigutchi, Professor at Tokyo Science University, who referred to precision manufacturing at the scale of nanometers. Nanotechnology typically uses particles in 10 nm-1µm range (Bayda *et al*., 2019).

In addition to the current Covid-19 pandemic situation, the global economy has been dramatically affected by all sectors, including agriculture and food production industries, by the global burgeon in human population and rapid urbanization. Therefore, the daunting task of feeding more mouths from agricultural lands in every year rapidly declining is left to the farmers in worldwide. Scientifically, it is evident that our earth is rapidly exhausting of fertile land and the production level of food shows a downward trend over the last decade, the food production will not be sufficient for the fulfillment of demand by the growing population in coming years, but people can contemplate a self sustainable world through only one field, *i.e*., agriculture. Though, the availability of land and water resources is limited, but the productivity in agricultural sector drastically increased with the extensive usage of modern technologies. Of late, nano application is among the revolutionary technology in agriculture domain. Nanotechnology possesses the potential role in agricultural productivity through genetic improvement of plants with cellular level delivery of genes and drug molecules to specific sites in MAPs through the suitable techniques and sensors in precision agriculture, natural resource management, and efficient delivery systems for agrochemicals (*e.g*., fertilizers and pesticides, food processing, packaging and food system security). Nanotechnology has potential vast applications in controlling nutrient release and availability, characterization and weathering of soil minerals, soil properties, and nutrient ion transport in soil plant system, water conservation with its treatment and efficient management of soil health including ground water pollution. Not only that, it also contributes in a broad way to ensure security of food, health, energy and environmental safety for the ever growing unabated Indian population (Figure 1). Recently, nanotechnology has found potential applications in weathering of soil minerals and development, nutrient ion transport in soil plant system, zeoponics, emission of dusts and aerosols from agricultural soils and their nature (Das, 2005; Mukhopadhyay *et al*., 2009).

Agriculture is the stable sector in India because it produces and provides raw materials for food and food industries. Due to the cultural conditions, the alteration in the MAPs growth and productivity are widely varied in the recent year (Mukhopadhyay, 2014). The most important challenges are depletion of natural resources,

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deterioration of soil nature, declining productivity resurgence of new pests and diseases, global warming and climate change that affects in sustainable development. Therefore, fertilization is one of the important activities that remain fundamental concern in improvement of soil fertility. But, the over dose of fertilizers may show the unwanted impacts, *viz.*, soil salinity, expansion of heavy metals, increment of nitrate, high enrichment of minerals in water, and even produces green house effect due to air contamination by nitrogen and sulfur (Savci, 2012; Fernández-Luqueño *et al.*, 2014). Hence, a novel multidimensional nanotechnology plays an immense role and potential impact in the fertilization domain of agriculture field by facilitating the slow and constant release of nutrients. The technology also decreases the loss of nutrients and improves the efficiency of the nutrients application in MAPs and apparently contributes significant enhancement in quality and quantity of biomass yields with minimal dependency on environment (Liu and Lal, 2015). Therefore, some important differences between nanofertilizers along with conventional or traditional fertilizers are listed in Figure 4. The beneficial impact of nanotechnology is mainly due to the properties of nanoparticles (NPs). Generally, these nanoparticles are formed chemically or physically but nanoparticles are also formed using microorganisms, enzymes, fungi, and also by plants or plant extracts which are ecofriendly (Konishi and Uruga, 2007; Ahmad *et al.*, 2011). In the nanoparticles, more atoms are present on the surface compared to the interior of the nanoparticles. This leads to large surface to volume ratio which in turn leads to higher charge density and high reactivity of nanoparticles. Importantly, silver, gold, alloy, magnetic nanoparticles are some important types which used in herbal field (Figure 2). Silver nanoparticles are effective against mainly bacteria, viruses and acts as potential antimicrobial agent (Rai *et al.*, 2009). Gold nanoparticles are used in immunochemical studies for identification of protein interactions, DNA finger printings for DNA identification, cancer stem cell detection, *etc.* (Tomar and Garg, 2013). Alloy nanoparticles contain structural properties among that bimetallic alloy nanoparticles show more efficiency than normal one in terms of improved electronic, optical and catalytic performances (Hasan, 2015) whereas, magnetic nanoparticles are useful for DNA analysis, targeted cancer treatment, stem cell manipulations, *etc.*, example, Fe_3O_4 (magnetite) and Fe_2O_3 (maghemite) which are biocompatible (Fan *et al.*, 2009).

In the nanofertilizer, the most important useful method is nano-biofertilizer which is a conjugate preparation and combinatorial practical application of nano and biofertilizers (including soil beneficial microbes) (Figure 3). The application of nano biofertilizer is improvement and sustainable crop productivity with environmental safety (Kalia and Kaur, 2019). In the present manuscript, the contribution of nanotechnology technique on development of nano fertilizer and its uses and function in soil are focused.

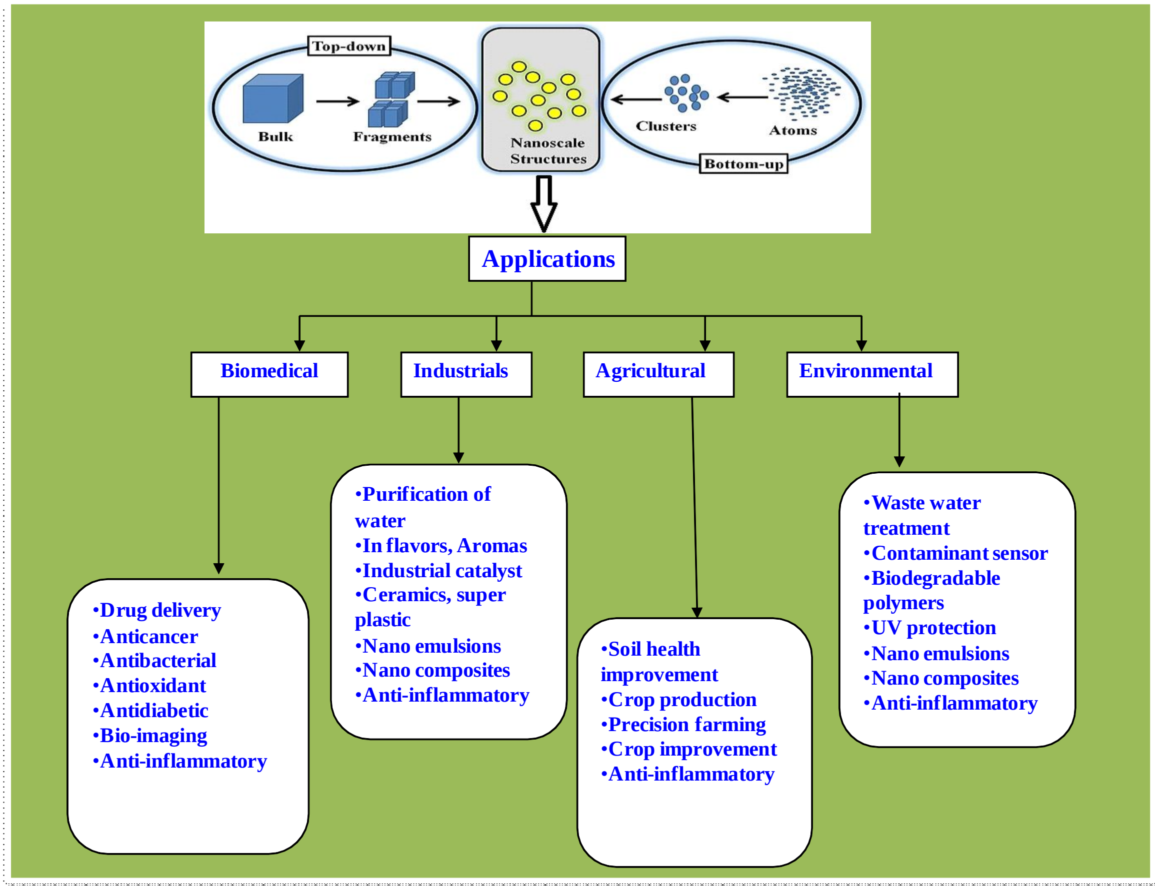
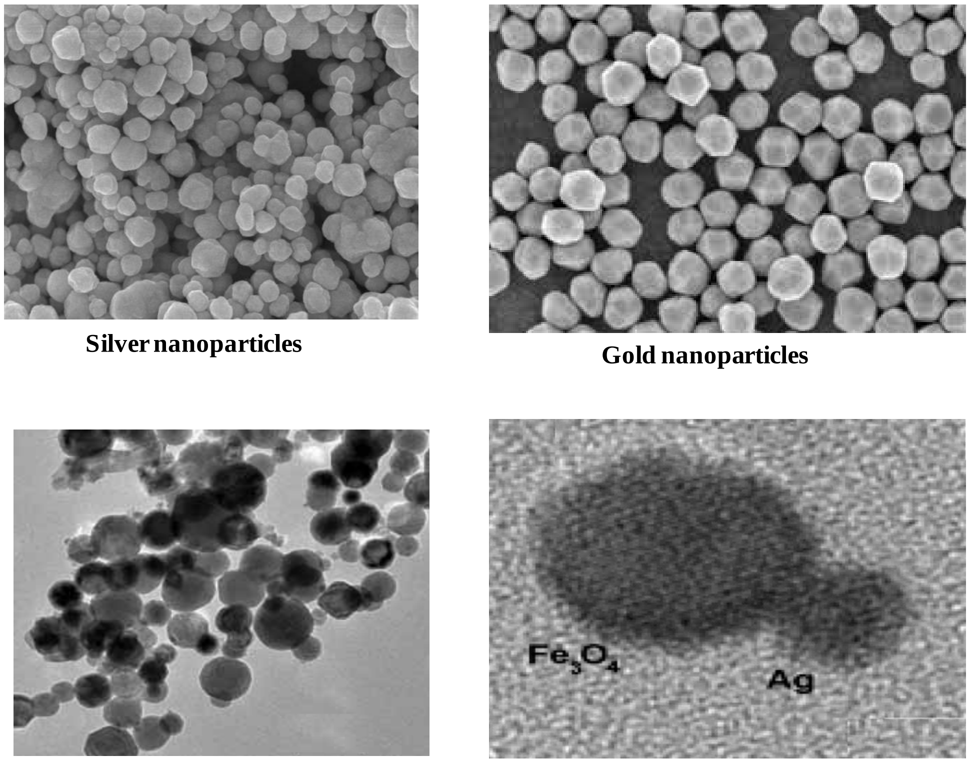


Figure 1: Application of nanoparticles in various fields.



Silver nanoparticles

Gold nanoparticles

Fe-Ni alloy nanoparticles

Magnetic nanoparticles

Figure 2: Types of nanoparticles.

2. Methodology

The informations in the present article are collected from the various latest research papers, bibliographic database, informations from the various official websites. Various databases like PubMed, PubMed Central., Science Direct, SCIELO, DOAJ, Science alert, Semantic scholar and Google scholar were used for the informations.

2.1 Unique features of nanoparticles (Khan *et al*., 2019)

1. Nanotechnology is applied in drug with various forms such as nanocrystals, liposomes, nanoparticle-protein conjugates, magnetic nanoparticles, nanogels and biodegradable nanoparticles.
2. The behavior of the atoms on the surface of the particles becomes more potent as compared to the atoms that are inside the particles due to increased surface area in comparison to volume.
3. As the size is smaller than the order of wave length, nanoparticles do not obstruct light.
4. As a result of large surface to volume ratio, there is more interaction between atoms in intermixed materials in nanoparticles, which leads to increased strength, increased heat resistance, decreased melting point and different magnetic properties of nanoclusters.
5. Differences in the exposed surfaces of different nanoparticles of various shapes leads to differences in atomic distribution across the nanoparticle.
6. The zeta potential of maximum nanoparticles is varied from +30 and -30 mv and show high tendency to agglomerate to higher particles sizes except hydroxyl apatite.

2.2 Nanoparticles in relation to soil health

1. Nanoparticles can play an important role in characterization and improvement of soil physical properties.
2. Characterization of soil properties such as physical infrastructure of soil micro aggregates of 10-50 µm scale can be done by using nanoscale secondary ion mass spectroscopy and microscopy.
3. Natural organic matter in soil or pore water can sorb, coat or stabilize nanoparticle suspensions and affect their mobility, bioavailability, reactivity and toxicity.
4. Synthetic nanocomposite polymer clays have high water retention capacity and can be used to conserve soil moisture in arid soil.
5. The soil nanoparticles showed a rapid initial phase (milliseconds) followed by a slow phase (days) in sorption of heavy metals, metalloids and organic contaminants due to diffusion in to microspores, structure rearrangement and precipitation nature of compounds.

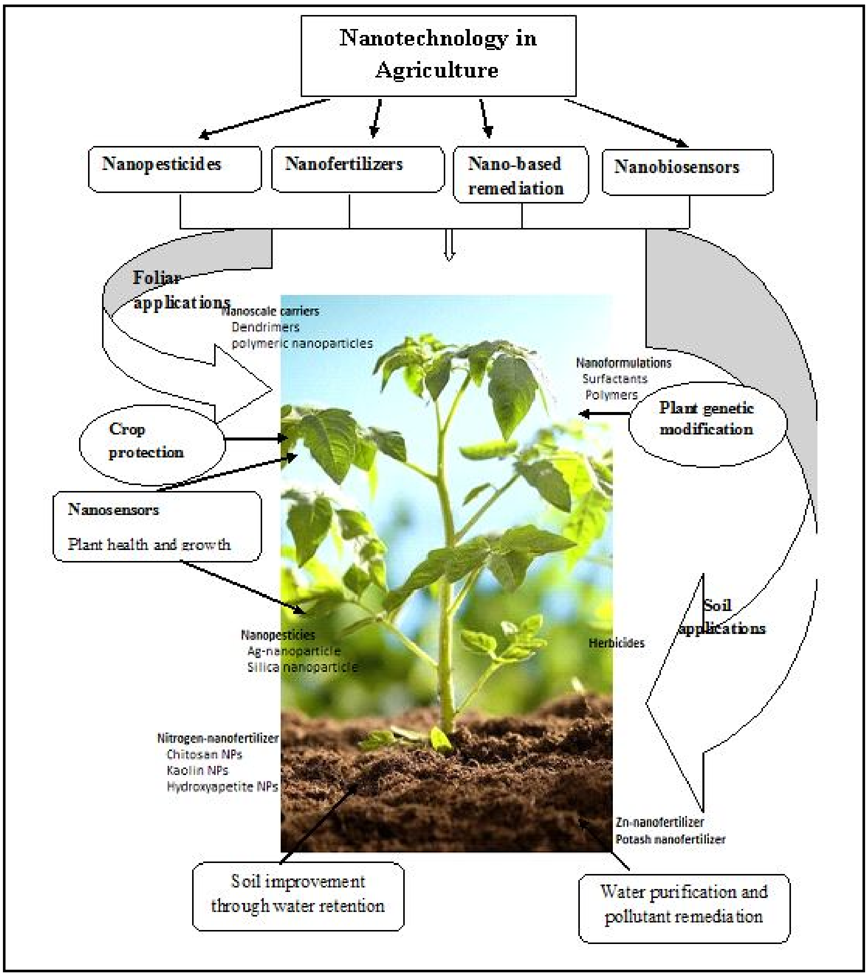


Figure 3: Applications of nanotechnology in MAPs.

2.3 Nanofertilizers and nutrient use efficiency

Nanofertilizers are defined as the nanoparticles that can directly/ augment supply of essential nutrients for plant growth, have higher nutrient use efficiency and can be delivered in timely manner to a rhizosphere target (soil) or by foliar spray. Not only that, nano-fertilizers help in improving imbalanced fertilization, depletion of soil organic matters, multi-nutrient deficiencies in MAPs, *etc.* As per the Indian Government data, the average utilization of fertilizers at around 500 lakh metric tonnes (LMT) in 2019-2020 and the same trend continued per year from last 10 years, but due to population growth, the demand for food is increased and side-by-side the application of the fertilizers are also enhanced. There are various types of nanofertilizers such as:

Slow release nanonitrogen fertilizer: Nano zeolite impregnated with urea causes slow and steady release of N. NH^+ ions occupying the internal channels of zeoloite slowly set free N allowing progressive absorption by the medicinal plants.

Slow release nanophosphate fertilizer: Surface modified zeolite (SMZ) has been found to be a well sorbent for PO_4^{-3}, and slow release of P is achievable (Giroto *et al.*, 2017).

Uptake of nanomicronutrients: Application of Zn nanoparticles (< 100 nm) at relatively lower level (0.28 ppm) enhanced the growth of maize plant as compared to normal zinc sulphate (0.5 ppm). The plant height, root growth and volume, dry matter weight can also improve with application of zinc oxide nanoparticles.

Based on the structure, nanofertilizers are nano porus zeolite, carbon nanotubes, boron nanofertilizer, zinc nanofertilizer, nanoherbicide, nanopesticide, nanofungicide, nanoaptamers. Nanoporus zeolites are the crystal form of aluminosilicate oxides, are widely used in catalysis and adsorption. Carbon nanotubes are cylindrical molecules with rolled-up sheets of single-layer carbon atoms that enhanced the yield of the MAPs. Boron and zinc nanofertilizers are most interesting nanofertilizers that enhanced both fruit yield and quality of MAPs. Herbicides are generally helps in weed controlling in MAPs but nano formulated herbicides are more effective formulation in sustained controlling of weeds with less quantity of applied herbicides. They are timed release and also have release linked to an environmental trigger. Not only nanoherbicides but also nano pesticides are also helps in controlling detrimental pests in the initial stages of plant growth. They have better permeability, biodegradable, effective control in longer period, and also decrease pest density in below the economic threshold level. Both nanoherbicides, nano- pesticides are applied in the form of nanocapsules, nanoemulsions, nanoparticles, *etc*. Thereafter, aptamers are short oligonucleotides that capable of specific binding to target with high affinity and widely applied in targeted nanodelivery systems. In MAPs, DNA aptamers are act as the optimal nanobiosensors that targets for binding the chemical interactions between the root system and the soil-micro-organisms and helps in identification of accurate specific chemical signals between the soil microbes and plant rhizosphere.

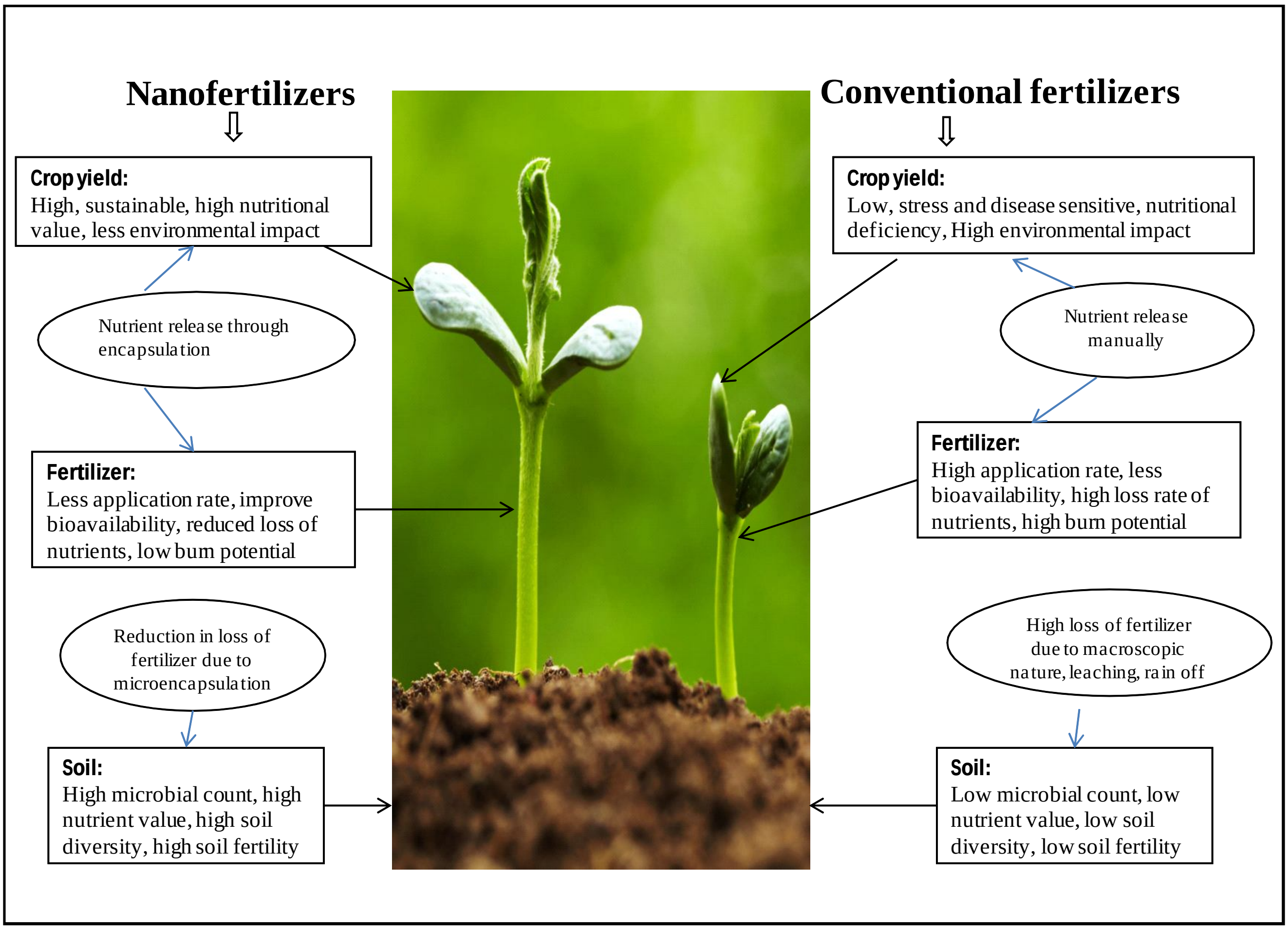


Figure 4: Some important difference between nanofertilizers and conventional fertilizers.

2.4 Nanotechnology in MAPs

Nano formulation with polysaccharides and triterpenes from *Ganoderma* spp. are showed an effective on antitumor, enhancing immunity and protecting liver and reducing blood pressure and triglycerides, respectively. Nanoliposome from *Antrodia cinnamomea* also showed effective for antietching, liver protecting, analgesic, and relief from alcohol hangovers. There are already preliminary results obtained from trials with nanoforms using turmeric, black pepper, berberine, trifla, black seed and more that give strong evidence to prove the concept of improved efficacy in reduction in these herbal preparations. In medicinal plant, *Stevia rebaudiana*, the main active principle stevioside is formed in nano size. PEG-PLA nanoparticles of size 150-170 nm is nano-bioconjugated for stevioside that showed the initial burst phase, followed by the slow controlled release of 2 h and 21 days, respectively which is helped for development of antidiabetic nanomedicine (Yadav *et al*., 2011). Mesoporous nanoparticles, the new breakthrough solution uses that are introduce the gene and activate it at the same time, in a precise and controlled manner and without toxic effects. Cassia twigs, liquorice root, sealwort are uses nanotechnology to reduce their active ingredients to the smaller sizes and that enabling them to enter cancerous cells without damaging healthy cells. The multi-walled carbon nanotubes are used to develop seed germination of tomato species (*Solanum lycopersicum*) (Khodakovskaya *et al*., 2009). Applications of TiO_2 nanoparticles enhanced 73% dry weight, multiple times higher photosynthetic rate, and 45% augmentation in chlorophyll in *Spinacia oleracea* (Lei *et al*., 2007). Foliar spray of gold nanoparticles increased stem diameter, plant height, number of pods, number of branches, and seed yield than the control on *Brassica juncea* (Arora *et al*., 2012). By the application of SiO_2 nanoparticles in *Carthamus tinctorius* plant enhanced the total biomass yield in terms of canopy spread, stem diameter, plant height, and the number of achenes in capitulum extensively (Janmohammadi *et al*., 2016). Thereafter, liposome based nanoparticles of green tea, *Aloe vera* is effective for efficient antioxidant properties. Various nano metals such as silicon (Si), palladium (Pd), gold (Au), and copper (Cu) showed the impact in seed germination of lettuce (*Lactuca sativa*) (Sadique *et al*., 2017). Likewise, ZnO and CeO_2 nanoparticles increased fruit quality, starch content in Cucumber (*Cucumis sativus*) at concentration of 400 ppm (Zhao *et al*., 2014).

3. Conclusion

Application of nanotechnology in herbals and in soil science is at nascent stage of development, and large gaps exist in our knowledge on the subject. Perhaps, application of nanotechnology in agriculture is a significant characteristic in releasing agrochemical such as, supply of macronutrients and micronutrients to the plants for healthy development. As such, fertilization helps in improvement in nutrient uptake efficiency as well minimize the soil contamination. Nanofertilizers show controlled release of agrochemicals through specific targeted site, toxicity reduction, and also increased content of nutrient utilization by the released fertilizers. Not only that, they convert poorly soluble, poorly absorbed biologically active substance into promising deliverable substances. Furthermore, multidisciplinary efforts are needed for successful utilization of the modern technology to have rewarding future of great social relevance.

Conflict of interest

The author declares that there are no conflicts of interest relevant to this article.

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