Chapter

Nanotechnological Approaches in Sustainable Agriculture and Plant Disease Management

Siddhartha Das and Sudeepta Pattanayak

Abstract

Every year approximately 30–50% of crops suffer with different kinds of biotic stresses. Rapidly growing agrochemical industries and their diverse products make the environment more toxic and simultaneously hazardous for plant heath and soil health. Such types of agrochemicals are toxic, hazardous, carcinogenic, non-eco-friendly. Therefore, this is the ideal time to think about some more effective alternatives against those problems. Nanotechnological approaches bring the alternatives in the form of decreasing toxicity, improving shelf-life, increasing solubility for poorly water-soluble agrochemicals, minimum use with maximum effect, slow leaching efficiency with long-term effect with coupling of eco-friendly naturalistic way. The way of nanoparticle application in agriculture, specifically disease management, is unique, where it can be used singly or by coupling with fungicidal, herbicidal, insecticidal, RNA-interference molecules. Though it has such a positive impact, very few products will be commercially available in our market due to high price of particular products and well-established long field trial efficacy detection among insect, pest-pathogen, and environment. Application of nanomolecules in other progressive fields has been emerging, whereas advancement in agricultural applications needs to be boosted up through skilled knowledge transfer and basic understanding of its fundamental aspect.

Keywords: nanotechnology, IDM, sustainable, eco-friendly

1. Introduction

The population of the world is increasing in an alarming rate. The global demand for food production will need to double by 2050. But, the climate change such as prolonged drought, sudden increase of temperature, unpredictable rains, and floods are the main barrier to achieve this global food demand [1]. Moreover, significant crop losses, that is, 20–40% per year due to some biotic causes is another major problem in worldwide basis [2]. The biotic causes mostly include insects, nematodes, pathogens, weeds, human, and animal interaction. Earlier studies revealed that approximately 20 and 26% yield loss occurred due to pathogen and insect infestation [3]. Most developed and developing countries depend upon chemical pesticides to control the diseases and pest incidence as these are easily available and show the result quickly. Industrial business and marketing policy also sometimes cross their barrier to gain some profit. Therefore human made behavioristic alteration of our environment also considered as a crucial responsible factor.

But they do not think those chemicals are harmful to the ecosystem, poisonous to beneficial insects, create pest resurgence, 90% loss of chemical during or post application in field leading to more economical loss for farmers. By keeping all the aforesaid reality based problem in mind, a new potential concept and technique known as nanotechnology is developed by the scientists, which is cost-effective, reliable, eco-friendly, and very effective. Although, this concept has not gained more focus in agriculture compared to pharmacology and medicine, but still it takes part a major role in plant breeding, nano sensors, plant hormone delivery, limited application of chemicals, plant health management etc. [4–6].

Nanotechnology refers to the technology related to application and manipulation of nanoparticles, that is, very small particles or materials having one or more dimensions, that is, 1–100 nm and fashioned with exclusive physical, chemical, and biological properties [7]. Several scientists have worked on the desired characteristics of nanoparticles such as pore shape, size etc. for accurate and specific application through adsorption or encapsulation of effective pesticide [8]. Application of nanoparticles can be functionalized in two ways, that is, first, nanoparticles directly involves as a plant protectant and second, nanoparticles used as carrier. On the first way researchers have tested the viability of the nanomolecules and mode of action against a particular pathogen. On the second way nanoparticles used with the existing fungicides or pesticide, herbicides, RNAi-mediated coupled component, to boost its activity. Nanoparticles used as a carrier have some positive sites like it can increase solubility of the coupled component, increase shelf-life, boosting site- and target-specific activity, reduce toxicity level, and maintain environmental safety. The implementation and utilization of fruits of nanotechnological applications, in terms of plant disease detection and management, gene editing and transformation is at infancy stage till now due to insufficiency of knowledge and skills. In the present context, the use of nanotechnology in plant disease management and allied sectors of agriculture is a real challenging task, which is objectified and framed with the present chapter.

Context of sustainable agriculture and nanotechnology

1. **Application of nanotechnology to increase crop productivity and quality:** A variety of nanoparticles were tested previously to study their efficacy for boosting the yield as well as quality of the crop. It was observed that the nanoparticles modify enzymatic action, electron transport system, and influence the nutrition uptake. Carbon nanoparticles are reported to increase the yield of bitter gourd by enhancing the biomass, water content, fruit weight, length, and number. Lentil seeds show high germination rate and growth when treated with silica-based nanoparticles. Titanium dioxide nanoparticles can boost the water uptake, breakdown of organic compounds, photosynthesis capacity, etc. [9].

2. **Increase of photosynthetic efficiency through nanotechnological application:** Seeds incorporated with nanoparticles can promote the photosynthetic activity in plants. The nanoparticles respond to a specific wavelength of light and increase the optical potential of leaves which in result effect the hills reaction. Titanium dioxide-based nanoparticles can enhance the water and nutrient uptake, light absorbance and activity of Rubisco activase enzyme resulting more photosynthetic activity in plants. These nanoparticles induce the plants to be photosynthetically more active, grow faster, resulting in quality food production in less period of time [9, 10].

3. **Improvement in water retention and management:** Nanotechniques can be imposed in agriculture to reduce the loss through evaporation, irrigation, and

to stabilize soil horizons in addition to lessening the ecotoxicity. Nanoparticles or nanotubes are found to be effective in retaining the water inside the hollow core for longer period by modifying the xylem vessel mechanism and metabolism of plant cells. Due to the partial solubility and dispersible characteristics, the water is retained inside plant cells for more time. In 2009, Corredor et al. demonstrated carbon nanotube treatment in pumpkin plant to analyze the water retention capacity and observed the accumulated carbon nanotubes inside the plant cell, which act as a water transporter. Due to the cohesive force, the water moves continuously through the nanotubes in plant cell forming a nanosized water stream [11].

4. **Significance in the field of plant disease management:** Recent days, nanotechnology is taking part a major role in plant disease management due to its eco-friendly nature and potentiality. Among all nanobased particles, silver nanoparticles stand out in the frontline in plant defense. These nanoparticles disturb the cell DNA, metabolic activity, electron transport chain, nutrient uptake of micro-organisms leading to death. The pathogenic fungi which can be controlled by using silver nanoparticles are *Colletotrichum gloeosporioides, Alternaria solani, Fusarium oxysporum, F. solani, Macrophomina phaseolina, Rhizoctonia solani, Aspergillus niger* etc. Silica-silver based nanoparticles are reported to inhibit the growth of bacteria *Pseudomonas syringae, Xanthomonas campestris* pv. *vesicatoria* up to 100%. Copper-based nanoparticles were found to be effective against bacteria *Xanthomonas oryzae*pv. *Oryzae*, *Xanthomonas campestris* pv. *phaseoli* and fungi *Fusarium solani, Alternaria solani, Aspergillus flavus* etc. [12, 13].

    A. **Limitations of different applied disease management strategies:** Drawbacks or limitation of all applied disease management practices are depicted under **Table 1**.

    B. **Types of nanoparticles for plant disease management:** Nanoparticles can be used to manage the plant disease through two different mechanisms: as protectants where the nanoparticles only protect the plants and as carrier where the nanoparticles contain potential pesticides or some other active compounds [2]. Schematic representations of mode of action of these two modes are shown under **Figure 1**.

        I. **Nanoparticles used as protectants:** Potential nanoparticles used alone to protect the plants from pathogenic micro-organisms and applied directly to plant and plant parts. Several metal nanoparticles like copper, silver, zinc oxide, titanium dioxide is experimented for their antagonistic effects against all pathogenic bacteria, virus, fungus, and concluded as successful potential protectants [14–16]. These nanoparticles have more shelf life, easily soluble in water, and show site specific uptake as compared to conventional chemicals.

            a. **Silver nanoparticle:** It is in the frontline due to its "green synthesis" production mechanism in bacteria, yeast, fungi, and plants [17]. From previous studies, it is reported that silver nanoparticles have antifungal effect against *Alternaria alternata, Sclerotinia sclerotiorum, Macrophomina phaseolina, Botrytis cinerea, Rhizoctonia solani,* etc. by well diffusion assay [18] while antiviral effect on sun hemp rosette virus when sprayed on leaves and bean yellow mosaic virus when applied after infection [19].

Techniques	Physical Method	Chemical method	Biological method
Strategies applied	Soil solarization	Fungicide, pesticide or related agrochemicals	Resistant varieties, Use of biocontrol agents
Limitations	• Longer duration • Selective towards thermophilic and thermotolerant pathogens • Climate dependent • Availability of crop-free fields for long period • Survival of pathogen in deeper soil zone • Pollution from plastic residue after treatment	• Resistance to fungicide or pesticide • Harmful effect on non-target organisms • Non ecofriendly • Carcinogenic • Non-economic	• Wide host range of pathogen • Survival of pathogen for long period • Costly • Lack of proper awareness and training

Table 1.
Limitations of different disease management prcatices.

b. **Nano carbon:** The carbon nanoparticles not only show antimicrobial activity in plant health management but also positively affect the plant growth. These nanoparticles from graphene oxide sheets have shown antimicrobial activity against *Aspergillus niger, A. oryzae, and Fusarium oxysporum in vitro* [20]. Many researchers have anticipated about the mechanism behind the inhibition of microbial growth by carbon nanomaterials and explained that the nano edges of graphene oxide come in direct contact with the chemical compounds present in cell wall of fungi and bacteria making them inactive [21–23].

c. **Titanium dioxide nanoparticle:** When this nanoparticle is used as fertilizer was known to show antibacterial, antiviral and insecticidal characteristics.

d. **Poly dispersed gold nanoparticles**: It was reported to inactive the Barley yellow mosaic virus and develop plant resistance [24, 25].

e. **Chitosan nanoparticles** control alfalfa mosaic virus, *Fusarium* spp., *Botrytis* spp., *Pyriularia grisea* while show limited effect against bacteria [26]. The mechanisms behind the antimicrobial properties of chitosan are inhibition of the growth of pathogen, protein synthesis, and ATPase activity, agglutination, interruption of cell membrane, disruption of nutrient flow etc. Chitosan nanoparticles have also been reported to control aphids, root knot nematode, and cotton leaf worm.

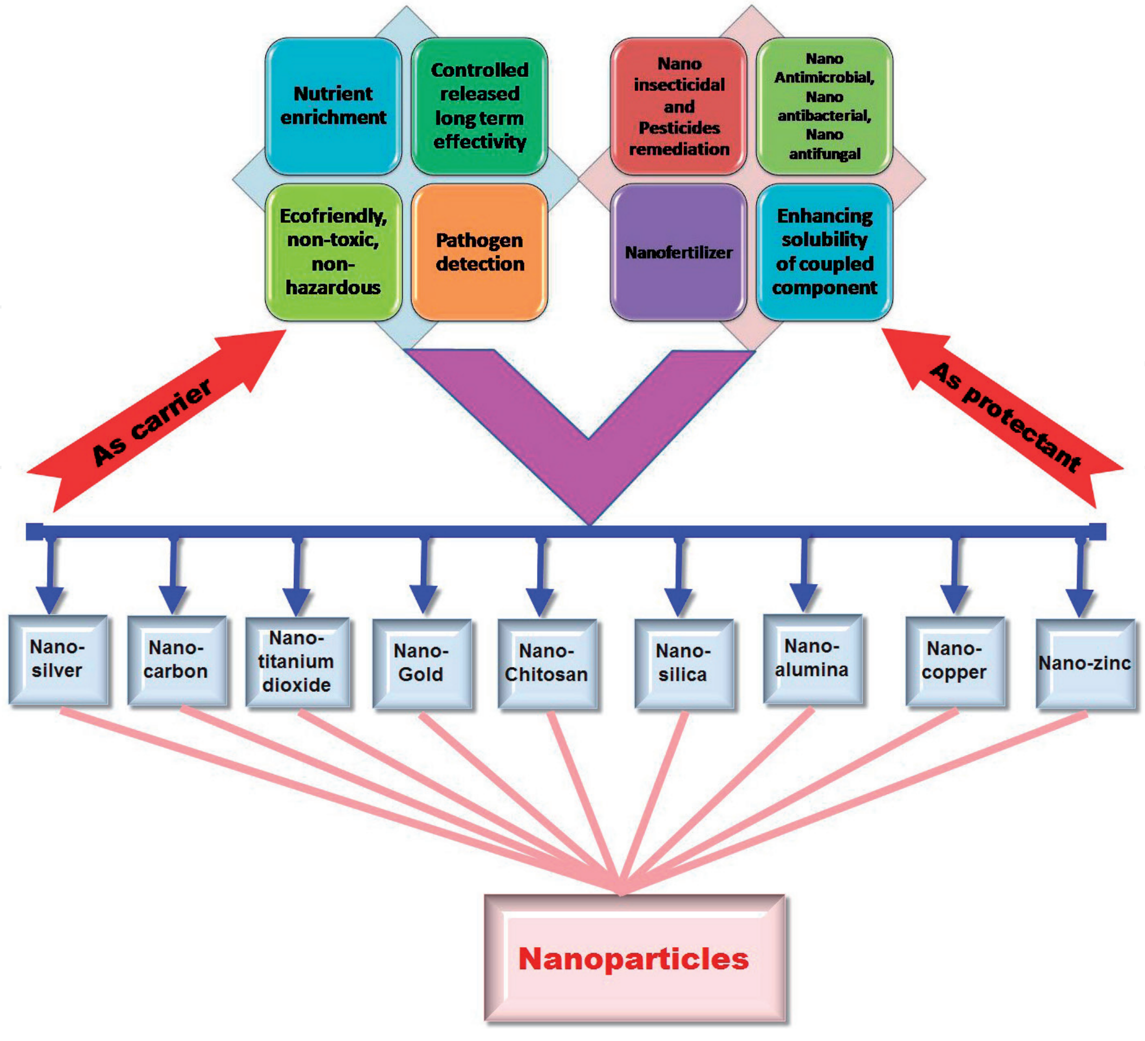

Figure 1.
Schematic representation of different nanoparticles and their mode of action in term of carrier and protectant.

II. **Nanoparticles that act as carriers:** Nanoparticles are engineered in such a way that these can carry, encapsulate, or absorb active potential compounds to develop effective agricultural pesticides. These carrier nanoparticle-based pesticides have less toxicity, slow leaching capacity, and highly target specific. The below-mentioned nanoparticles are mainly used as carrier:

a. **Silica nanoparticles:** These nanoparticles have specific size, shape, and structure making them able to deliver the active compounds in the target site [27]. They are mainly round or circular like structure having a pore like holes, for example, mesoporous silica nanoparticles (MSNs) or porous hollow silica nanoparticles (PHSNs). The active compounds are mainly loaded in the inner hole to keep them protect and proper release in target sites. The outer shell guards the active compounds against degradation by UV light.

b. **Nano alumino-silicate**: The major advantages for the use of nano alumino-silicate are that it is biologically active, eco-friendly, and more effective than other nanoparticles. The alumino-silicate nanotube containing active compounds when sprayed on plants, the insects present on plants intake the active compounds contained nanotubes [28].

c. **Chitosan nanoparticles:** Due to the low solubility in aqueous media, chitosan nanoparticles are applied by mixing with some organic or inorganic or copolymer compounds to increase its solubility [29]. These compounds stick to the stem and leaf epidermis facilitating them for prolonged effect in target sites [27]. Presence of amines and hydroxyl groups, enable the nanoparticles to enhance its properties [30].

d. **Nanocopper:** Copper is one of the most effective and potential chemicals in combating wide range of plant diseases. For the first time in 2013, Giannousi et al. studied the potential antimicrobial characteristics of nanocopper particles and concluded that the nanocopper particles are more promising than other copper-based chemicals [31]. From past studies, it was reported to control or minimizes the growth of the pathogen of Fusarium wilt of tomato, *Verticillium* wilt of eggplant, Leaf spot, leaf blight diseases etc. [32, 33]. Biosynthesized nanocopper derived from *Streptomyces griseus* was observed to limit the growth of *Poria hypolateritia* causing root rot disease of tea [34].

e. **Nanozinc:** The characteristic antimicrobial properties of nanozinc particles are mostly studied in vitro condition. It was reported to control bacteria, fungi, for example, *Alternaria alternata, Botrytis cinerea, Sclerotinia sclerotiorum, Rhizopus stolonifera, Rhizoctonia solani, Mucor* spp.*, Fusarium oxysporum,* and *Penicillium* spp. [35, 36]. Disease suppression in protected cultivation and green house condition through nanozinc is also possible.

f. **Solid lipid nanoparticles (SLNs):** These nanoparticles contain lipids, which remain in solid state at room temperature. Therefore, the lipophilic compounds show its prolonged effect by slow releasing of active compounds without adding any extra organic solvents [37]. The limitations are that the active compound may escape during storage [38].

g. **Layered double hydroxides (LDHs):** These nanoparticles break down when come in contact with water or carbon dioxide [39]. The positively charged LDH nanoparticles make the active compounds easier to move through the plant cell wall.

h. **Nanoemulsions:** Nanoemulsions are combination of more than one liquid that does not mix easily. These nanoparticles contain active ingredients in the droplets of diameter 500 nm or less and lessen the degradation of chemicals or active ingredients inside [35].

i. **Dendrimers:** These nanoparticles are branched, similar to tree like structure, having a central core, which is occupied by functional groups [1]. Very few reports and research have done on dendrimers related to plant pathology. It can be referred as a great delivery vehicle as it can transport chemicals or pesticides in basipetal manner after a foliar spray. It can enhance the permeability in diseased plant cells.

III. Application of nanoparticles to boost/develop commercial agro-protectants (herbicide/fungicide/insecticide)

a. **Nanoparticles as carriers for herbicides:** Nanocarrier-based herbicide studied mainly confined to reduce the environmental toxicity, which occurs due to conventional herbicides. The herbicides, carrier-based nanoparticles with target pest and toxicity is listed in the below **Table 2**.

b. **Nanoparticles as carriers for fungicides:** The mostly used nanoparticle carriers for fungicidal use are silica, chitosan, polymer mixes etc. Nanoparticles for carrier-based fungicides are much popular as they can reduce the loss through volatilization, increase solubility and release chemicals at target sites slowly. The list of nanocarrier-based fungicide, its target pest with crop details, is given in below **Table 3**.

c. **Nanoparticles as carriers for insecticides:** Nanoparticles can be used to lower the toxicity level while increasing its solubility in water. Additionally, these particles lessen the volatilization loss resulting effective protection on targeted sites. The nanoparticles as carrier of insecticide, its target and crop details given in the below-mentioned **Table 4**.

IV. **Application of nanoparticles in gene delivery system and to moderate gene expression:** The nanoparticles can be referred as molecular cargo as they can easily transfer the genetic materials such as nucleic

Nanoparticle	Herbicide	Target pest	Toxicity or soil leaching	Reference
Chitosan	Paraquat (L)	Maize, Mustard	Chinese hamster ovary cells *A. cepa*, Soil sorption	[40]
SLN	Simazine (C)	*R. raphanistrum*	Mouse fibroblast cells Maize	[41]
Chitosan/tripolyphosphate	Imazapic (B) and Imazapyr (B)	Black-jack (*B. pilosa*)	Chinese hamster ovary cells *A. cepa* Soil biota	[42]
Chitosan	Diuron (C)	*E. crusgalli*	Maize	[43]
Nanosized rice husk	2,4-D (I)	Maize	*Brassica Sp.* Soil sorption	[44]
Polymer	Metolachlor	*D. sanguinalis*	Preosteoblast cell line (mammal)	[45]
Polymeric	Simazine (C)	-	*C. elegans*	[46]

Table 2.
Nanocarrier-based herbicidal characterization and their target pests [40–46].

Nanoparticle	Fungicide	Target pest	Crop	Reference
Silver	Tebuconazole Propineb Fludioxonil	*Bipolaris maydis*	-	[47]
PVP and PVP copolymer	Chlorothalonil, Tebuconazole	*Gloeophyllum trabeum*	Southern pine sapwood	[48]
Gold	Ferbam	-	Tea	[49]
PVC	Chlorothalonil, Tebuconazole	Turkey tail (*T. versicolor)* *G. trabeum*	Southern yellow pine and Birch pine	[50]
Bacterial ghosts	Tebuconazole	*L. nodorum, E. graminis, S. fuliginea* and *P. teres*	Wheat, Barley and cucumber	[51]
Chitosan	Carbendazim	*F. oxysporum*and *A. parasiticus*	Cucumber, Maize, Tomato	[52]

Table 3.
List of nanocarrier-based fungicides and their application in plant disease management [47–52].

Nanoparticle	Insecticide	Target pest	Crop	Reference
Silica	Chlorfenapyr	*H. armigera, P. xylostella*	*Brassica chinese*	[53]
Sodium alginate	Imidacloprid	Leafhopper (Jassids)	-	[54]
Dendrimers	Thiamethoxam	Cotton bollworm cells and larvae (*H. armigera*)	-	[55]
Chitosan	Azadirachtin	Tobacco cutworm (*S. litura*) culture ovarian cell lines	-	[56]
PHSN	Avermectin	*P. xylostella* larvae	*Brassica oleraeea*	[57]
Zinc oxide and chitosan	Azadirachtin	-	Groundnut bruchid (*C. serratus*)	[58]
Polydopamine	Avermectin	-	Cotton leaves and corn leaves	[59]

Table 4.
Nano-protectant with insecticidal activity [53–59].

acids to the target site and induce to express the new genetic material in the recipient. Surface-functionalized vertically arranged carbon nanofibers act as molecular cargo and carry the plasmid DNA to the desired site, expressing the characters in the recipient similar to other conventional methods. Researchers had developed a fluorescent labeled starch nanoparticle-based transgene vector that is able to enter the plant cell and nuclear membrane to deliver the genetic materials. In this system, ultrasound and fluorescent label help in gene delivery by producing transient pores and visual tracking of transgene respectively. Some nanoparticles carry the genetic material by holding it tightly so that it will not get detached from the nanoparticle thereby expressing for short time without integrating to the genetic material of the recipient. Apart from this, sometimes nanoparticle-based gene transfer show negative effect by modifying some genes.

V. **Nanoparticles used for abiotic stress tolerance:** Nanoparticles are reported to reduce or tolerate abiotic stress like salt stress, heavy metal toxicity, biotic stress etc. In addition to this, nanoparticles can provide mechanical strength to plants, promote germination and seedling growth, help in nutrient and water uptake, etc. Zinc, copper, and iron nanoparticles are observed up to 40 times less lethal than their salts. Hence, these nanoparticles widen the scope for more productivity than other salt-based applications [60]. In 2014, Sabaghnia and Janmohammadi reported that SiO_2nanoparticles enhanced germination percentage, shoot and root length, seedling fresh and dry weight in lentil plant [61]. In 2017, Taran et al. concluded that the drought tolerance in winter wheat can be alleviated by inducing higher antioxidant enzyme activity when treated with the colloidal solution of Cu and Zn nanoparticles [62].

C. Preparation of silver nanoemulsion

a. **Wet chemistry method:** This method is one of the best methods in preparation of silver nanoemulsion as it combines in molecular level and versatile in nature. This method is first time carried out by Guzman et al. in 2009. In this method, silver nitrate, hydrazine hydrate, and sodium dodecyl sulfate act as metal precursor, reducing agent, and stabilizing agent respectively. The creation of silver nanoparticles was observed with the help of UV-Vis absorption spectroscopy [63].

b. **Ion implantation method:** This method was carried out by Popok and his coworkers in 2005. In this method, silver ions were implanted to synthesize the metal nanoparticles in SiO_2 by using 30 KeV energy and ion current density of 4–15 $\mu A/\ cm^2$. The analysis of this new compound was done by using optical spectroscopy and atomic force microscopy [53].

c. **Physical vapor deposition:** This method was explained by Lin and his coworkers in 2003. In this method, the overall size of silver trifluoroacetate reduced up to 7–11 nm under isoamyl ether and oleic acid solution by properly maintaining the temperature variation. This process is widely accepted and very smooth to manage [54].

5. **Nanotechnological applications to reduce postharvest loss:** Nanotechnology can be used to limit the post-harvest loss of solid, liquid or processed food

items and beverages. A sensory coating is applied on the product through wrapping or encapsulation method, which slightly modifies the color of the product by improving the taste and shelf-life of the food item. Thin layer of nanoparticles protects the food products from spoilage by holding moisture. Some of the nanoparticles proven promising in lessening the post-harvest loss are carbon nanoparticles, zinc oxide etc., which are mainly antibacterial [9].

6. **Nanotechnological applications in agriculture and animal husbandry:** In livestock management and animal husbandry, nanochips are installed in poultry and livestock to check their health and behavior through sensory technique. Quality of the poultry and livestock products can also be tested by using this method. The quality of meat or any contaminated particles present in it can be checked to avoid microbial spoilage [64]. In case of milk and milk products, **pasteurization** and improved nutrition to increase its quality are the possible ways through nanotechnological system. If nano carrier-based particles are employed in egg production, it will lessen pathogenic infection and transport the nutrients properly resulting quality egg production [65].

7. **Nanotechnological applications in fishery and aquaculture:** Nanotechnology is found to be one of the effective methods in aquaculture in order to increase the nutritional quality like protein and oil and also to promote the health of the fish and other sea foods [9]. Sensory-based drug delivery system was proved to be promising in detection of pathogen present in fish thereby promoting good health and quality nutrition. Nanoparticles mixed in water can also detect the presence of algae or any other micro-organisms and control eutrophication by reducing the phosphorus compounds [66]. Additionally, the encapsulated nanoparticles can effectively be used for fish feed, promoting the fish growth, increasing water quality etc. [67].

8. **Waste management approaches through nanotechnological applications for sustainable agriculture:** Researchers have done enough study on sustainable management of both solid and liquid waste in such a way that it can reduce the soil and water contamination. Scientists observed that implementation of nanotechnique, for example, bionanomaterials and nanobiomimics in waste management is a promising solution. Nanofibers can effectively be used to prepare absorbable substances that can degrade the waste materials in less time without leaving any toxic substances in addition to improve the production and quality of biomass [9].

9. Concerns about nanotechnology in terms of environmental protection as well as human development:

    a. **Toxicological and environmental safety concerns:** The more use of nanoparticles can lead to negativity on agriculture as many nanosubstances have proven toxic to some beneficial micro-organisms. The uncontrolled application of nanobased agrochemicals can usher to environmental pollution and disturbances in food chain. Before mass release of any nanoparticles, it should be checked properly for safety protocols of toxic composition and its residual effect [9]. A previous study has reported that the pure aluminum-based nanoparticles inhibit root growth of many plants while aluminum oxide-based nanoparticles act as a pollutant and hamper crop growth [68]. Similarly, nanozinc oxide-based products improve the food quality of soybean while nano-CeO_2 has reported to reduce the soybean yield and nitrogen fixing potential [69]. Therefore, the nanobased products should be in controlled use with prior precaution measures and existing regulatory frameworks to lessen the negative effects on agriculture.

b. **Legal and regulatory action:** Nonhomologous legal protocols refer to nano entities. In some developing countries like India, some compounds or particles with known application characteristics, if modified to nanoparticles, it will not be registered under patent. Section 3d of Indian patent act limited or restricted the common or already known materials from patent registration thereby opening the ways to do more research on it [70]. These types of laws have widened the paths to find out the scope of nanotechnological application, which will lead to sustainable agriculture.

c. **Socioeconomic perspective:** The nanotechnological application not only used to get more benefits in case of farmers as well as entrepreneur but also to take our agricultural system toward sustainability. All the nanoproducts should be properly labeled, which will make the farmers to choose the required products. Nanoparticles and nanofibers can improve the efficacy of agrochemicals in less period of time. The use of natural occurring nano formulations is very old. The potentiality of these formulations is very large, which can be known from the patents registered from last year's [9].

2. Summary and future scope

Nanotechnology is one of the emerging methods in agriculture that can bring revolution to bring sustainability. Nanotechnology is not only the potential solution for agriculture but also in other allied sectors like animal husbandry, dairy, poultry, fishery etc. The use of nano-components is one of the potentials, eco-friendly and economical method by using the entire proper regulatory framework. This method should be followed properly by keeping in view of all ethical, regulatory, toxic, and policy concerns. The nanoparticles should come in to market after repeated experiment both in vitro and lab condition.

Nanotechnology helps to developed multiple new methods for green house to field disease management as well as new area of molecular editing and manipulation for plants and pathogenic stress. Therefore diverse nanoparticles like nano-Ag, nano-Cu, nano-Zn used as potential arsenal against various destructive diseases which causes severe yield loss. One of the most important or striking feature is that considerable amount of reduction of metals compared to inorganic agrochemicals. Using of carbon nanoparticles to control disease is also under trial. Every time one thing must be remembered whenever any metal or metallic ions we are applying for nanomaterial preparation, that must be consumable through food chain additionally nontoxic and nonhazardous. It is also found that mechanism of action for each disease, different diseases on the same host and different diseases on various hosts are not the same way of treatment. Because the mode of action is different for each cases. Application of nano-globule in organic farming system is slowly upgrading and matter under consideration of developing countries agricultural policy. Some countries used copper oxychloride, copper hydroxide and copper oxide in their organic farming system in very lesser amount. Application of nanocopper in organic farming system found to be very effective for its sustainable, environment friendly and long term approach. Researchers are trying to develop micro and macro nutrient enriched plant growth nano promoter. This type of nano-complex not only gives protection against various destructive diseases but also enhancing the plant growth with its slow leaching compatibility mode. Application of different metallic ions and carbon-nanomer under genetic delivery system is the modern topic of research. Introduction of modern tolls like quantum dots and biosensor (with combination of nanotechnology) in plant pathology can greatly replace conventional ELISA technique for plant viral detection.

The use of nanobased pesticide, herbicide and fungicide, is an attractive advancement in plant health management keeping in focus of the healthy environment. It has the ability to deliver the pesticide to the specified target with low evaporation loss, improve the solubility, overcome resistance of pesticide in insects and pests, and have better shelf-life. Due to lacking of long-term based in vivo experimental trial, observation or monitoring, more research should be carried out on the particular field. To brand this method as a successful one, material scientists and biologists should cooperate with each other to gain more deep knowledge on complex nanosystems. The reliable, efficient nanoparticles should be chosen that can be biocompatible and no harmful to the plant system. Before releasing, any nanoparticles-based products in to the market, their toxicity, impact on environment, and other risk assessment factors should be analyzed properly. This method is yet to reach to the farmers mostly in developing countries. Therefore, government should work on this to create awareness among the farmers. The journey of nanotechnology in plant disease management and different other sectors of agriculture is under progressive research and wide adaptation through farmers level. The multidisciplinary nanotechnological approaches needs support from government and government-induced schemes or policies and also support from funding agencies, which will lead to a sustainable agriculture system by lessening the global food production as a challenge for future.

Conflict of interest

The authors solemnly and confidently declared that they have no conflict of interest. They are not attached with any other academic or research institutes, except the mentioned affiliation in terms of contribution. Additionally, they also declared that they are not attached with any kind of financial interests or non-financial (or personal interests) interests with any other organization or person. The subject matter of this chapter is totally original and unique or if taken from any other literature properly cited under the references of this manuscript.

DOI: http://dx.doi.org/10.5772/intechopen.92463

Author details

Siddhartha Das* and Sudeepta Pattanayak
Department of Plant Pathology, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi Odisha, India

*Address all correspondence to: siddhartha.das10@gmail.com

References

[1] Elmer W, White JC. The future of nanotechnology in plant pathology. Annual Review of Phytopathology. 2018;**56**:111-133

[2] Worrall EA, Hamid A, Mody KT, Mitter N, Pappu HR. Nanotechnology for plant disease management. Agronomy. 2018;**8**(285):1-24

[3] Bhattacharjee R, Dey U. An overview of fungal and bacterial biopesticides to control plant pathogens/diseases. African Journal of Microbiology Research. 2014;**8**(17):1749-1762

[4] Sinha K, Ghosh J, Sil PC. New pesticides: A cutting-edge view of contributions from nanotechnology for the development of sustainable agricultural pest control A2—Grumezescu, AlexandruMihai. In: New Pesticides and Soil Sensors. Cambridge, MA, USA: Academic Press; 2017. p. 5

[5] Balaure PC, Gudovan D, Gudovan I. Nanopesticides: A new paradigm in crop protection. In: New Pesticides and Soil Sensors. Academic Press; 2017. pp. 129-192

[6] Hayles J, Johnson L, Worthley C, Losic D. Nanopesticides: A review of current research and perspectives. In: New Pesticides and Soil Sensors. Academic Press; 2017. pp. 193-225

[7] Sekhon BS. Nanotechnology in Agri-food production: An overview. Nanotechnology, Science and Applications. 2014;7:31-53

[8] Yang W, Peters JI, Williams RO. Inhaled nanoparticles—A current review. International Journal of Pharmaceutics. 2008;**356**:239-247

[9] Podder K, Vijayan J, Ray S, Adak T. Chapter 10: Nanotechnology for sustainable agriculture. In: Singh RI, Mondal S, editors. Biotechnology for Sustainable Agriculture: Emerging Approaches and Strategies. United Kingdom: Woodhead Publishing; 2018. pp. 281-303

[10] Noji T, Kamidaki C, Kawakami K, Shen JR, Kajino T, Fukushima Y, et al. Photosynthetic oxygen evolution in mesoporous silica material: Adsorption of photosystem II reaction Centre complex into 23 nm nanopores in SBA. Langmuir. 2011;**27**(2):705-713

[11] Corredor E, Testillano PS, Coronado MJ, Gonzalez-Melendi P, Fernandez-Pacheco R, Risueno MC. Nanoparticle penetration and transport in living pumpkin plants: In situ subcellular identification. BMC Plant Biology. 2009;**9**(1):45

[12] Gogoi R, Dureja P, Singh PK. Nano formulations: A safer and effective option for agrochemicals. Indian Farming. 2009;**59**(8):7-12

[13] Essa AMM, Khallaf MK. Antimicrobial potential of consolidation polymers loaded with biological copper nanoparticles. BMC Microbiology. 2016;**16**:144

[14] Kah M, Hofmann T. Nanopesticide research: Current trends and future priorities. Environment International. 2014;**63**:224-235

[15] Gogos A, Knauer K, Bucheli TD. Nanomaterials in plant protection and fertilization: Current state, foreseen applications, and research priorities. Journal of Agricultural and Food Chemistry. 2012;**60**:9781-9792

[16] Kim DY, Kadam A, Shinde S, SarataleRG PJ, Ghodake G. Recent developments in nanotechnology transforming the agricultural sector: A transition replete with opportunities. Journal of the Science of Food and Agriculture. 2018;**98**:849-864

[17] Rafique M, Sadaf I, Rafique MS, Tahir MB. A review on green synthesis of silver nanoparticles and their applications. Artificial Cells, Nanomedicine, and Biotechnology: An International Journal. 2017;**45**:1272-1291

[18] Krishnaraj C, Ramachandran R, Mohan K, Kalaichelvan P. Optimization for rapid synthesis of silver nanoparticles and its effect on phytopathogenic ungi. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2012;**93**:95-99

[19] Jain D, Kothari S. Green synthesis of silver nanoparticles and their application in plant virus inhibition. Journal of Mycology and Plant Pathology. 2014;**44**:21-24

[20] Wang X, Liu X, Chen J, Han H, Yuan Z. Evaluation and mechanism of antifungal effects of carbon nanomaterials in controlling plant fungal pathogen. Carbon. 2014;**68**:798-806

[21] Berry TD, Filley TR, Blanchette RA. Oxidative enzymatic response of white-rot fungi to single walled carbon nanotubes. Environmental Pollution. 2014;**193**:197-204

[22] Chen J, Wang X, Han H. A new function of graphene oxide emerges: inactivating phytopathogenic bacterium, *Xanthomonas oryzaepv*. oryzae. Journal of Nanoparticle Research. 2013;**15**(5):1658

[23] Liu S, Wei L, Hao L, Fang N, Chang MW. Sharper and faster "nano darts" kill more bacteria: A study of antibacterial activity of individually dispersed pristine single-walled carbon nanotube. ACS Nano. 2009;**3**(12):3891-3902

[24] Elbeshehy EKF, Elazzazy AM, Aggelis G, et al. Frontiers in Microbiology. 2015;**6**:453

[25] Alkubaisi NAO, Aref NMMA, Hendi AA. Method of inhibiting plant virus using gold nanoparticles. US Patents US9198434B1, 1 December 2015; 2015

[26] Kochkina Z, Pospeshny G, Chirkov S. Inhibition by chitosan of productive infection of T-series bacteriophages in the *Escherichia coli* culture. Mikrobiologiia. 1994;**64**:211-215

[27] Kashyap PL, Xiang X, Heiden P. Chitosan nanoparticle-based delivery systems for sustainable agriculture. International Journal of Biological Macromolecules. 2015;**77**:36-51

[28] Patel N, Desai P, Patel N, Jha A, Gautam HK. Agro nanotechnology for plant fungal disease management: A review. International Journal of Current Microbiology and Applied Sciences. 2014;**3**(10):71-84

[29] Mody VV, Cox A, Shah S, Singh A, Bevins W, Parihar H. Magnetic nanoparticle drug delivery systems for targeting tumor. Applied Nanoscience. 2014;**4**:385-392

[30] Malerba M, Cerana R. Chitosan effects on plant systems. International Journal of Molecular Sciences. 2016;**17**:996

[31] Giannousi K, Avramidis I, Dendrinou-Samara C. Synthesis, characterization and evaluation of copper-based nanoparticles as agrochemicals against *Phytophthora infestans*. RSC Advances. 2013;**3**(44):21743-21752

[32] Elmer WH, De La Torre-Roche R, Pagano L, Majumdar S, Zuverza-Mena N, et al. Effect of metalloid and metallic oxide nanoparticles on *Fusarium* wilt of watermelon. Plant Disease. 2018;**102**(7):1394-1401

[33] Evans I, Solberg E, Huber DM. Copper and plant diseases. In: Datnoff LE, Elmer WH, Huber DM,

editors. Mineral Nutrition and Plant Disease. St. Paul: American Phytopathological Society; 2007. pp 177-188

[34] Ponmurugan P, Manjukarunambika K, Elango V, Gnanamangai BM. Antifungal activity of biosynthesised copper nanoparticles evaluated against red root-rot disease in tea plants. Journal of Experimental Nanoscience. 2016;**11**(13):1019-1031

[35] He L, Liu Y, Mustapha A, Lin M. Antifungal activity of zinc oxide nanoparticles against *Botrytis cinerea* and *Penicillium expansum*. Microbiological Research. 2011;**166**(3):207-215

[36] Wani AH, Shah MA. A unique and profound effect of MgO and ZnO nanoparticles on some plant pathogenic fungi. Journal of Applied Pharmaceutical Science. 2012;**2**(3):40-44

[37] Li M, Huang Q, Wu Y. A novel chitosan-poly (lactide) copolymer and its submicron particles as imidacloprid carriers. Pest Management Science. 2011;**67**:831-836

[38] Ekambaram P, Sathali AAH, Priyanka K. Solid lipid nanoparticles: A review. Scientific Reviews and Chemical Communications. 2012;**2**:80-102

[39] Tamjidi F, Shahedi M, Varshosaz J, Nasirpour A. Nanostructured lipid carriers (NLC): A potential delivery system for bioactive food molecules. Innovative Food Science and Emerging Technologies. 2013;**19**:29-43

[40] Grillo R, Pereira AE, Nishisaka CS, de Lima R, Oehlke K, Greiner R, et al. Chitosan/tripolyphosphate nanoparticles loaded with paraquat herbicide: An environmentally safer alternative for weed control. Journal of Hazardous Materials. 2014;**278**:163-171

[41] De Oliveira JL, EVR C, Gonçalves da Silva CM, Pasquoto T, Lima R, Fraceto LF. Solid lipid nanoparticles co-loaded with simazine and atrazine: Preparation, characterization, and evaluation of herbicidal activity. Journal of Agricultural and Food Chemistry. 2015;**63**:422-432

[42] Maruyama CR, Guilger M, Pascoli M, Bileshy-José N, Abhilash P, Fraceto LF, et al. Nanoparticles based on chitosan as carriers for the combined herbicides imazapic and imazapyr. Scientific Reports. 2016;**6**:19768. DOI: 10.1038/srep19768

[43] Chidambaram R. Application of rice husk nano sorbents containing 2, 4-dichlorophenoxyacetic acid herbicide to control weeds and reduce leaching from soil. Journal of the Taiwan Institute of Chemical Engineers. 2016;**63**:318-326

[44] Tong Y, Wu Y, Zhao C, Xu Y, Lu J, Xiang S, et al. Polymeric nanoparticles as a metolachlor carrier: Water-based formulation for hydrophobic pesticides and absorption by plants. Journal of Agricultural and Food Chemistry. 2017;**65**:7371-7378

[45] Popok V, Stepanov A, Odzhaev V. Synthesis of silver nanoparticles by the ion implantation method and investigation of their optical properties. Journal of Applied Spectroscopy. 2005;**72**(2):229-234

[46] Lin X, Teng X, Yang H. Direct synthesis of narrowly dispersed silver nanoparticles using a single source precursor. Langmuir. 2003;**19**:10081-10085

[47] Huang W, Wang C, Duan H, Bi Y, Wu D, Du J, et al. Synergistic antifungal effect of biosynthesized silver nanoparticles combined with fungicides. International Journal of Agriculture and Biology. 2018;**20**:1225-1229

[48] Liu Y, Yan L, Heiden P, Laks P. Use of nanoparticles for controlled

release of biocides in solid wood. Journal of Applied Polymer Science. 2001;**79**:458-465

[49] Hou R, Zhang Z, Pang S, Yang T, Clark JM, He L. Alteration of the non systemic behaviour of the pesticide ferbam on tea leaves by engineered gold nanoparticles. Environmental Science & Technology. 2016;**50**:6216-6223

[50] Liu Y, Laks P, Heiden P. Controlled release of biocides in solid wood. II. Efficacy against *Trametes versicolor* and *Gloeophyllum trabeum* wood decay fungi. Journal of Applied Polymer Science. 2002;**86**:608-614

[51] Hatfaludi T, Liska M, Zellinger D, Ousman JP, Szostak M, Jalava K, et al. Bacterial ghost technology for pesticide delivery. Journal of Agricultural and Food Chemistry. 2004;**52**:5627-5634

[52] Kumar S, Kumar D, Dilbaghi N. Preparation, characterization, and bio-efficacy evaluation of controlled release carbendazim-loaded polymeric nanoparticles. Environmental Science and Pollution Research. 2017;**24**:926-937

[53] Song MR, Cui SM, Gao F, Liu YR, Fan CL, Lei TQ, et al. Dispersible silica nanoparticles as carrier for enhanced bioactivity of chlorfenapyr. Journal of Pesticide Science. 2012;**37**: 258-260

[54] Kumar S, Bhanjana G, Sharma A, Sidhu M, Dilbaghi N. Synthesis, characterization and on field evaluation of pesticide loaded sodium alginate nanoparticles. Carbohydrate Polymers. 2014;**101**:1061-1067

[55] Liu X, He B, Xu Z, Yin M, Yang W, Zhang H, et al. A functionalized fluorescent dendrimer as a pesticide nanocarrier: Application in pest control. Nanoscale. 2015;7:445-449

[56] Lu W, Lu ML, Zhang QP, Tian YQ, Zhang ZX, Xu HH. Octahydrogenated retinoic acid-conjugated glycol chitosan nanoparticles as a novel carrier of azadirachtin: Synthesis, characterization, and in vitro evaluation. Journal of Polymer Science, Part A: Polymer Chemistry. 2013;**51**:3932-3940

[57] Kaziem AE, Gao Y, Zhang Y, Qin X, Xiao Y, Zhang Y, et al. Amylase triggered carriers based on cyclodextrin anchored hollow mesoporous silica for enhancing insecticidal activity of avermectin against *Plutella xylostella*. Journal of Hazardous Materials. 2018;**359**:213-221

[58] Jenne M, Kambham M, Tollamadugu NP, Karanam HP, Tirupati MK, Balam RR, et al. The use of slow releasing nanoparticle encapsulated Azadirachtin formulations for the management of *Caryedon serratus* O. (groundnut bruchid). IET Nanobiotechnology. 2018;**12**:963-967

[59] Jia X, Sheng WB, Li W, Tong YB, Liu ZY, Zhou F. Adhesive polydopamine coated avermectin microcapsules for prolonging foliar pesticide retention. ACS Applied Materials & Interfaces. 2014;**6**:19552-19558

[60] Sytar O, Novicka N, Taran N, Kalenska S, Ganchurin V. Nanotechnology in modern agriculture. Physics—Alive. 2010;**9**:113-116

[61] Sabaghnia N, Janmohammadi M. Effect of nano-silicon particles application on salinity tolerance in early growth of some lentil genotypes. Annales UMCS. 2014;**69**:39-55

[62] Taran N, Storozhenko V, Svietlova N, Batsmanova L, Shvartau V, Kovalenko M. Effect of zinc and copper nanoparticles on drought resistance of wheat seedlings. Nanoscale Research Letters. 2017;**12**:60

[63] Guzman M, Dile J, Godet S. Synthesis of silver nanoparticles by

chemical reduction method and their antibacterial activity. International Journal of Chemical Engineering and Applications. 2009;**2**:3

[64] Rajkumar RS, Kandeepan G, Prejit Susitha K. Poultry research priorities to 2020. In: Sasidhar PVK, editor. Proceedings of National Seminar. Contributory Papers. Izatnagar, India: Central Avian Research Institute; 2006

[65] Kannaki TRV, Verma PC. Poultry research priorities to (2020). In: Sasidhar PVK, editor. Proceedings of National Seminar. Keynote Addresses and Lead Papers. Izatnagar, India: Central Avian Research Institute; 2006b. pp. 273-277

[66] Copetti D, Finsterle K, Marziali L, Stefani F, Tartari G, Lurling M. Eutrophication management in surface waters using lanthanum modified bentonite: A review. Water Research. 2016;**97**:162-174

[67] Van Oosterhout F, Lurling M. The effect of phosphorus binding clay (Phoslocks) in mitigating cyanobacterial nuisance: A laboratory study on the effects on water quality variables and plankton. Hydrobiologia. 2013;**710**:265-277

[68] Burklew CE, Ashlock J, Winfrey WB, Zhang B. Effects of aluminum oxide nanoparticles on the growth, development, and microRNA expression of tobacco (*Nicotiana tabacum*). PLoS One. 2012;**7**(5):e34783

[69] Priester JH, Ge Y, Mielke RE, et al. Soybean susceptibility to manufactured nanomaterials with evidence for food quality and soil fertility interruption. Proceedings of the National Academy of Sciences. 2012;**109**:E2451-E2456

[70] Reddy SBAP. The "efficacy" of Indian patent law: Ironing out the creases in section 3(d). SCRIPTed. 2008;**5**:1-35