Chapter 8
Nanotechnology for Detection and Diagnosis of Plant Diseases

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Contents

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1 Introduction

Nanotechnology is the science of building macromolecular or nano-materials, structures, devices, and even systems. It is also used for agriculture to make easy and better understanding of mechanisms of biological entities at cellular levels (Karunakaran and Jayas 2005). Diagnosing a plant disease by the use of nano-biotechnology is termed as nano-diagnostics. This chapter deals with how nano-technology plays an important role in controlling plant diseases. Nanotechnology can also assist to study disease diagnostics/prevention. In fact, the most commonly used techniques viz., DNA/protein microarrays, enzyme-linked immune sorbent assay (ELISA), polymerase chain reaction (PCR), fluorescence resonance energy transfer (FRET)-based analysis, etc. (Shi et al. 2006), have or can benefit from nanotechnology.

Nano-phytopathology is an intensive science for the detection of plant diseases. There is a probability in the future to achieve some success that will be discussed. Nanotechnology provides better solutions to numerous problems in plant diseases (Abd-Elsalam and Prasad 2018, 2019). This chapter addresses the use of nanotechnology to fight plant diseases for a sustainable future. The nano-material solutions for the protection of plants from various pathogenic bacteria, fungi, nematodes, and viral agents are also emphasized here. Screening and diagnosis of diseases, treatment in-farming practices, including pest and detection and control of the vectors, which carries viruses, etc. (Karunakaran and Jayas 2005). Diagnosis of a disease in plants at very early stage can play a vital role in treatment. The nanoparticles which have been used in managing plant diseases include nanoforms of, carbon, silver, silica, and alumina–silicates (Sharma et al. 2012). Hydrogen has the smallest atoms in which they are nearly about quarter of nanometer diameter; therefore, nanotechnology must build its molecules and atoms in which the upper limit is more or less but around the size of the phenomenon that was not observed and can be made use in the field of nanoscience or nanodevice (Ganji and Kachapi 2015) (Fig. 8.1).

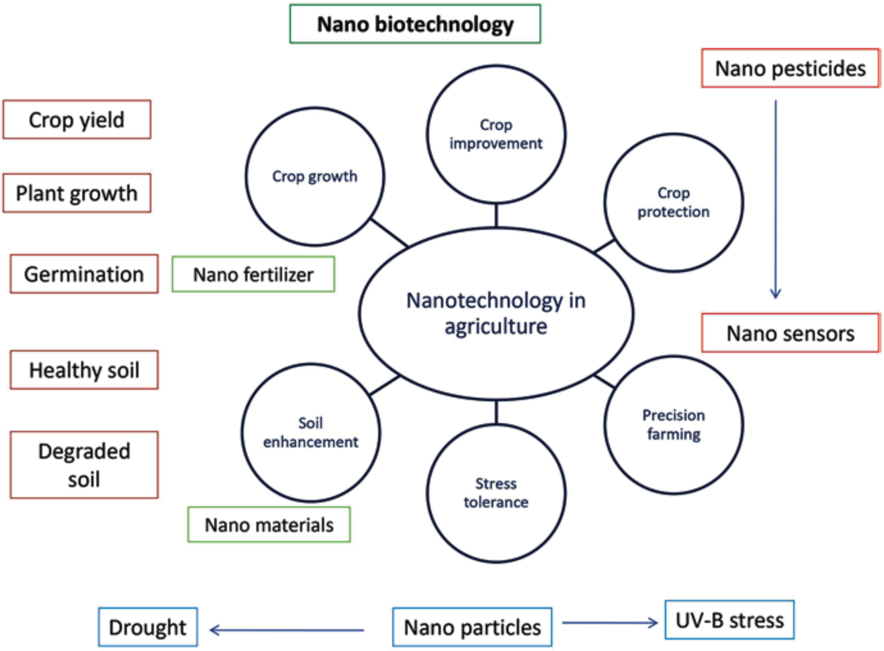

Fig. 8.1 Nanotechnology in agriculture

2 Nanotechnology in the Detection of Pathogens

It is notable that new techniques of disease detection involving nano-biosensors (Yalcin and Otles 2010) which is a fast and instant detection tool that can provide desired results within a few period of time (h). To identify the plant pathogens, the researcher needs prompt techniques and detection tools which can provide better results in short period of time. Detailed description of different detection techniques is discussed below (Fig. 8.2).

3 Tools of Nanotechnology

3.1 Nanodiagonastic Kit

A portable kit is used in the crops sown for the search of pathogens. This is a fast and accurate procedure to detect potential serious phytopathogens, which helps expert scientists in the prevention of epidemics of plant diseases from breaking out (Pimentel 2009). Very soon the plant pathologists are able to study the nanodiagnostic kit as a "lab in a box." This refers to packaging of sophisticated measuring devices, reagents, power supply, and features that now take up the laboratory space

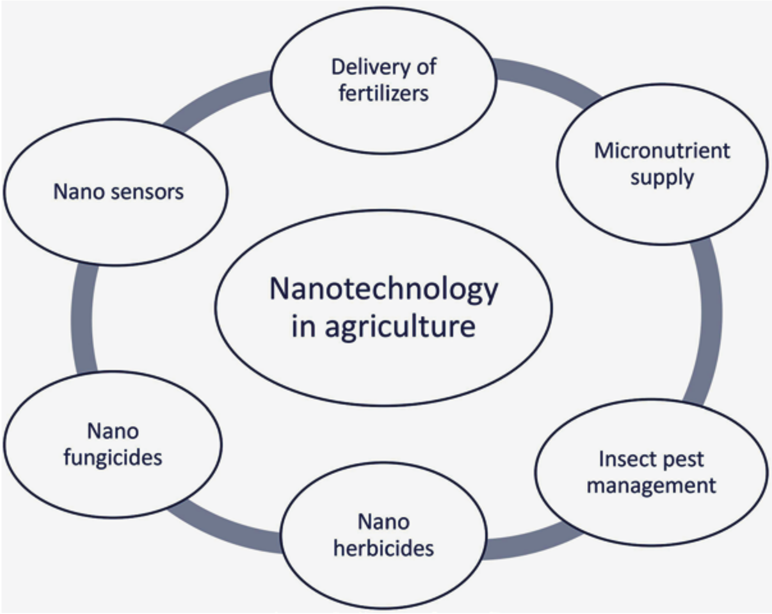

Fig. 8.2 Nanotechnology in agriculture

into a parcel no larger or heavier than a briefcase (Goluch et al. 2006). A briefcase kit is transferred to a field where the crops are growing to search for the pathogens that could infect and reduce the yield. This is a quick and precise procedure.

3.2 Nanoscale Biosensor

Some biological and chemical sensor points used to transmit nanoparticle data to the macroscopic world are nanosensors. Antibodies are flexible and are appropriate for varied immunosensing applications. It allows instant detection of a wide range of pathogens. In addition, it also gives numerous advantages viz., high sensitivity, potential for quantification, real-time analysis, pathogen detection in water, air, and seeds with different parameters. Biosensors are analytical device those used for detection and diagnosis of plant disease and their management an analytical device used for the detection of an analyze, the combines a biological component with a physicochemical detector. A highly sophisticated biological element such tissues of organisam and receptors sites like tissue, cell receptors, etc., is biologically derived material or biometric compound, which interacts or binds to analyze or under study (Turner et al. 1987; Singh et al. 2020).

3.3 Antibody Biosensor

Antibody-based biosensor plays a vital role in agricultural detection of plant pathogens. These biosensors enable the detection of plant pathogen in seeds, soil, air, and water with different principles in field conditions, greenhouses and as well as post-harvest storages along with the distributors of crops and fruits. Antibody biosensors have an efficient power in detecting the foodborne diseases and in which the techniques have already evolved for food safety monitoring. Besides, these biosensors provide various advantages such as improving in sensitivity, real-time analysis, fast detection, and potential of quantification. Antibody immune sensor lies in the specific antibody with a transducer that connects the binding event in which (the specific antibody can bind to specific antigen, e.g., interests of the pathogen) to that particular signal can be analyzed. Antibody biosensors mostly use only one type of electrochemical transducers such as impedimetric, conduct metric amperometric, and potentiometric). Impedimetric biosensors play an important role in the biomass detection based on the metabolic redox actions of microorganisms. On the other hand, the conduct metric On other hand conduct of metric and biosensors are used to detect the biological signal which is converted into an electrical signal through conductive polymer such as polypyrrole, polyacetylene, polyaniline, etc. The other types of transducers which are nonelectrochemicals that includes Quartz crystal microbalance (QCM), surface plasma resonance (SPR). Due to their attachment of the analytic on their metal surface, these SPR biosensors can change the measure of refractive index. On the other hand, mass variation per unit area can be detected through QCM by measuring the frequency change of a quartz resonator.

3.4 Gold Nanoparticles and Quantum Dots (QDs)

Gold nanoparticles based biosensors have been developed for finding the wheat disease viz. karnal bunt. For specific identification between the phytopathogen target cells and bifunctional nanomaterials, different techniques including adhesion receptor, antibody–antigen, and complementary DNA sequence can be recognized. Electrochemical procedures can be able to identify the pathogens by the use of gold nanoparticles which are having excellent markers that act as a biosensor. Besides these nanoparticles are also used along with the other biological materials for detecting antibody, for example, *Xanthomonas axonopodis* which causes bacterial spot disease. Several number of experiments have been conducted on nano-based particle to detect and develop the bimolecular DNA or protein-functionalized nanoparticles that have been used for specific target probes. In recent studies, various nano biosensors of agroterrorism and molecular diagnosis can be detected. QDs are semiconductor nanoparticles. QDs which are inorganic fluorophores having major advantages are used as markers also. In unicellular yeast, mycosynthesis of nanoparticles of semiconductor was first reported. For the biosynthesis, different microbes are used but, only few studies have been focused in luminescent properties. QDs are used as markers on proteins and nucleic acids for visual detection (Khiyami et al. 2014) as well as used for construction of biosensor designed for disease detection. Nanochips which are made of microarrays that contain fluorescent oligo probes which help in detecting single nucleotide change in viruses and bacteria. Many fluorescence resonance energy transfer (QD-FRET) sensors have been developed for disease detection in plants. For example, in *Rhizomania* disease, *Polymyxa betae* (Keskin) (Joshi et al. 2019) are the only known vector of BNYVV (Beet necrotic yellow vein virus) for the transmission of the virus to the beet plants, which were reported to be detected with QD-FRET-based sensor.

3.5 Nanofabrication

Nanofabrication is basically used for the development of artificial plant parts like xylem vessels and stomata. This process is helpful for the study of infection and behavior mechanism of plant pathogens inside host plant for example *Uromyces appendiculatus* (fungus causing rust disease of bean). *Colletotrichum graminicola* (fungus causing anthracnose in corn), and *Xylella fastidiosa* (xylem limited bacterium causing Pierce's disease of grapevine). All these pathogen infection mechanisms are studied by using nanofabrication tools.

3.6 Portable Nanopore Sequencing and Genome Sequence

Next-generation sequencing (NGS) technologies worked as key in recent decades to dramatically reduce the cost and time for pathogen identification with metagenomics strategies. Nano pore sequencing is also known as fourth-generation DNA sequencing technology. Application of external charges the electrolytes in the solution move from one side to another nanopore electrophoretically, due to which generates quantifiable ionic current. The first beta-testing of Minion can simplify the work by connecting to a USB port. As this device works with the flow of cells where the nana pore cells are mobilized; 5–10 Gb of sequencing information will be generated by each flow of cells. By the use of Minion, suitable work can be made in the remote location with small-sized particles (Quick and Choo 2017). Application of this device has also been tested in International Space Centre (NASA 2016). When the DNA strands move through biological nanopores by applying an electric field the Minion technology measures its rate, and also helps in detecting the translocation of DNA molecule (Jain 2003). It has been widely used to identify viruses without culturing, and using environmental samples directly, in the field of plant pathology (MacDiarmid et al. 2013; Boonham et al. 2014). However, till date the majority of the experiment on NGS assays are done in particular laboratories, require costly equipment, and complicated data algorithm (Feng et al. 2015). Nano pore technology is thought to be straight forward. The DNA passes into the nano pore and a direct electronic analysis is conducted. For the control of single standard DNA, an enzyme and a protein were designed. At the top of each micro well, this protein nano pore was inserted with a polymer bilayer membrane. A sensor chip has been inserted on each micro well in which the ionic current that has a single molecule passes through the nanopore.

3.7 Portable PCR Systems and Portable Equipment

Portable PCR is used for the amplification of DNA and agarose gel detection of pathogen which is efficiently used for amplification and detection of different types of samples plant pathogens. It will also not only simplify the detection techniques for the identification of plant diseases but also provides an effective way to do other tests at molecular levels. The amplified DNA is long enough to carry out agarose gel detection. This portable type of system provides an effective way to perform different types of PCR techniques for detection and diagnosis purposes. Comparing with the other techniques, the TWISTA quantitative and portable real-time fluorimeter provides a real-time analysis for examining the recombinase polymerase amplification. The advantages of portability and speed provide more efficiency in testing the DNAs for further analysis. Comparing with other traditional microbiological assays, Twista RPA fluorometer will supply instant fast diagnosis which requires a molecular assay in centralized equipment that can be done in the least hours (Fig. 8.3).

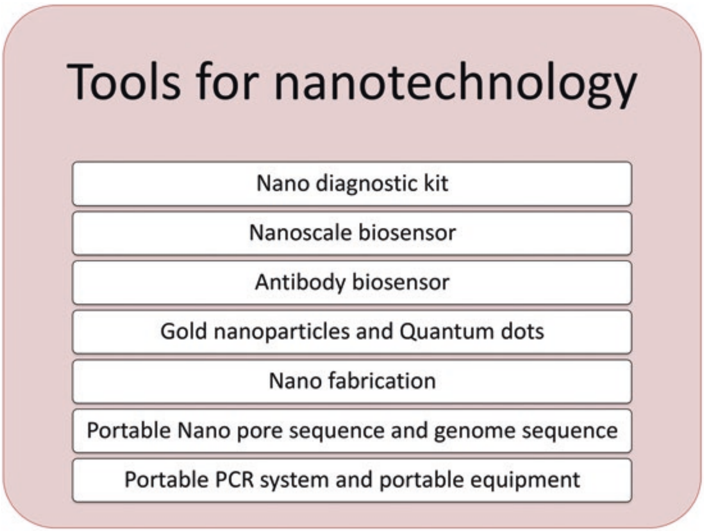

Fig. 8.3 Tools of nanotechnology

3.8 Nanotechnological Advancement of Plant Pathogen Identification and Diagnosis

Nanotechnology is an newly emerged science for identification of real cause of disease or disorder due to the biotic, mesobiotic, and abiotic factors, which is also useful for identification and elimination of latent types of symptoms of diseases or disorders such as viral and viroid diseases and nutrient-deficient expression of plant.

3.9 Fluorescent Silica Nanoparticles Merge with Antibody Molecules (FSNP)

Silica nanoparticles are used for detection and diagnosis of entity of several diseases of crop plants. Mostly fungal and bacterial are diagnosed with the help of Fluorescence silica nanoprobe that acts as a biomarker is used to detect *axonopodis* pv of *Xanthomonas*.

4 Modified Copper Nanoparticles with Gold Electrode

Copper nanoparticles with gold electrode with electrolytic oxidation help in the detection of fungal pathogen *Sclerotinia sclerotiorum* of rapeseed crop.

4.1 QD Cadmimumtelluride Thioglicolic Acid

Use of quantum dots (FRET) biosensors could detect *Polymyxa betae*, acting as a beet necrotic yellow virus (BNYVV) vector, in sugar beet *Rhizomania* disease and *Candidatus Phytoplasma aurantifolia*.

4.2 Nano Structural Layer of Biosensors and CuO Nanoparticles

CuO nanoparticles synthesis and manufacture of biosensors for nanostructural layers to detect the fungus *Aspergillus niger*.

4.3 Carboxylic Groups Contain Modified QD

Devise of the DNA biosensor based on the fluorescence energy resonance transfer (FRET) for detection of *Ganoderma boninense* synthetic oligonucleotide, a pathogen of the oil palm.

4.4 Nanoribbon and Nanorod

Nanoribbon polypyrrole chemiresistive immuno sensors are used for the detection of viral pathogen, whereas nano rod-based fiber is used for the detection of orchid virus.

4.5 Carbon Electrodes are Screen Printed by TiO_2 and SnO_2 Nanoparticles

By using oxide nanoparticles, the fungi-infected fruit can be detected with the help of electrochemical detection of p-ethylguaiacol.

4.6 Silver Nanoparticle and Nanowire

Plant diseases can be detected by the use of nanowire-based biosensor. Isothermic based amplification with combination of chip hybrids may be used for the detection of selected *Phytophthora species.*

4.7 Metal Diagnostics Nanoparticles

Biochemical sensors metal nanoparticles can be used as marker tags to replace enzymes as the name. Voltammetry striping can detect nanoparticles of metal directly making the test simple. The gold (AuNP) and silver nanoparticles (AgNP) can be used for analytical detection using these techniques, including various inorganic nanocrystals (ZnS, PbS, and CdS) (Upadhayayulva 2012). The last 15 nucleotides are in addition to a sequence of one half the target. Once objective DNA is inserted into the process, all AuNP forms bind to an aggregate DNA. Colloidal AuNPs are highly sensitive and selective than conventional strategies. They can be used to detect specific pathogen goals (Khan and Rizvi 2014). The AuNP system has two AuNP types: each covered with various thiol oligonucleotides. Oxanica

(UK) Quantum dots and MultiPlx Beads™ from Crystalplex Corporation, USA (Tothill 2011) are the various products which are available in the market. Nanoparticles can also be used in conductivity sensors in which a signal change can be caused upon the attachment of the antigen to the sensor surface with nanoparticles (Servin et al. 2015). Different strategies have been developed for accurate detection between the target phytopathogenic cells and biofunctionalized nanomaterials, including antimicrobial antibodies, adhesion receptor, antibiotic, and DNA complementary sequence recognition. Gold nanoparticles are good markers in biosensors because optical and electrical pathogens can be easily changed. Singh et al. (2010) exploited a plasma resonant (SPR) based on nanogold immunosensors capable of detecting karnal bunt disease of wheat (*Tilletia indica*). Gold nanoparticles "capacity to act as quenchers for fluorescent labeling at the end of 50 of DNA oligonucleotides and coupled with gold nanoparticles at 30" (Dubertret et al. 2001; Thakur et al. 2020). The treatment of phytoplasmas associated with grapevine dore'e flavescence (FD) demonstrated improvement in the application of these oligonucleotides (Firrao et al. 2005). Gold nanoparticles have opened new prospects for optical production of nano biotransducer quality for diagnostically purposes to quench fluorescence from light harvester polymer, such as polyfluorene (Fan et al. 2003). Oligo AuNP probes are hybridized with oligonucleotide-functionalized magnetic microparticle (MMP) probes in the case of oligonucleotide targets using the target sequence as a linker. Such complexes are then magnetically isolated from the oligo-AuNP probes for subsequent release of the oligonucleotides. The scan metrical studies evaluate these published biobarcodes quantitatively. The experiment allows rapid identification in engineered conditions (Goluch et al. 2006) of nuclear acids at high zeptomolar concentrations (Nam and Kim 2004) and protein targets at low molar values. In combination with on-chip hybridization in order to detect plants and *Phytophthora*, Schwenkbier et al. (2015) developed a helicase-dependent isothermal amplification (HDA). This method enables an effective amplification of the GTP (Ypt1) target gene region of the yeast in a miniaturized heating system at a constant temperature. DNA hybridization in chips and subsequent silver nanoparticles deposition were used to determine the specificity of the sample. This is a step toward onsite and simultaneous detection of several types of plant pathogens. It is a sign of the silver deposits that enables both visual and electrical readout. The use of nanostructures, due to its high surface-to-volume ratio, size-dependent electric properties, and possibilities for device miniaturization, has been expanded in the advancement of nanotechnology and biotechnology as a new platform diagnosis (Prieto-Simon et al. 2007; Sertova 2015). The design of pathogen-sensing platforms and mycotoxin determination platforms is based on nanoparticles, such as carbon nanomaterials (carbon nanotubes and graphene), nanocomposites, and nanostructured nano metal oxide nanoparticles (Abu Salah et al. 2015). The large format and potential to detect interesting compounds in timely sample volumes at high speed are a major benefit of such systems (García Alvarez et al. 2010). The set of thousands of nanoparticles developed by Bhattacharya et al. (2007) was visualized in different colors in contact with food pathogens. The micronutrients are other types of nanostructure platforms, which can also efficiently and highly sensitively detect pathogens in real time (Baeummer and Dhawan 2004).

4.8 miRNA Expression Pattern in Diseased State

Different biological processes such as cell growth and growth, biogenesis, transduction of signal, and apoptosis are involved with miRNAs. Genetic alterations are often caused by miRNA genes because it is found in fragile region of the genome. Horseradish peroxidase (HRP) biosensors were also used for the detection in spiking beer and roasted coffee without any pretreatment. For the detection of ultra-trace amounts of aflatoxinM1 (AFM1 (up to 0.01 ppb) produced by *Aspergillus flavus*, Paniel et al. (2010) used magnetic nanoparticles to improve the electrochemical immune sensor. Hervas-Stubbs et al. (2011) described the "lab on chip" strategy for the fast, sensitive, and discriminatory quantification of *Fusarium* sp generated zearalenone by means of an electrokinetic magnet-based electrochemical immunoassay in a microfluidic chip. Ansari and Raghava (2010) have shown that solgel-based nanoZnO film can be used to block rIgG or BSA for detecting 0.0060.01 nM OTArange detection from unspecific binding sites of r-IgG. Kaushik (2013) have developed a film-based immunosense nanostructuring cerium oxide detective method for foodborne mycotoxins. Rabbit immunoglobulin anti-conservation and BSA are immobilized on a cerium oxide film synthesized with a soil-free nanostructure on an indium oxide plate to detect ochratoxins. Mak et al. (2012) stated that for the detection of more than one mycotoxin ultrasensitive magnetic nanoparticle is used.

The gap between the clay layers has been extended ten times by the use of nano-sized clay and nanoclay can therefore bind the entire mycotoxin family. In combination with smaller water molecules and smaller mycotoxins, as aflatoxin and ochratoxin, silica, and clay are most efficient. Moreover, clays are less active in binding large mycotoxins, including fumonisin and vomitoxin, since there is not enough space between the layers of clay to accommodation in larger molecules (Jaynes et al. 2007). The use of superparamagnetic nanoparticles enhances a simple enzyme-connected immune sorbent assay (ELISA) (Radoi et al. 2008). A 4-mercaptobenzoic acid-based monolayer on a gold electrode (ABA/Au) to produce the BSA/aAFB1CAuNP/MBA/Au immune electrode was immobilized for cysteamine functional gold nanoparticles (C-AuNP) together with aflatoxin-B1 anticorps (aAFB1). Such electrodes have been used to detect AFB1 between 10 and 100 ng L^1 (Sharma et al. 2010). A moving machine has recently been developed which can at the same time identify different bacterial, fungal, and pathogenic toxins in stored food (Biswal 2012; Yalcin and Otles 2010).

From all these studies, nanostructured platforms seem to be a promising alternative to traditional mycotoxin and pathogen detection techniques which ruin foodstuffs and farm crops.

4.9 Nanobiosensor Diagnostics

Nanosensors selective for target analyte molecules with immobilized bioreceptor samples are called nano biosensors. They are highly sensitive, accurate, quantorial, precise, reproducible, and reliable and thus can be used for minute quantification and identification in agriculture and food systems for the use of pollutants such as viruses, bacteria, fungi, toxins, and other biohazardous substances (Srinivasan and Tung 2015; Singh et al. 2020). Such sensors can be connected to GPS and distributed in the field to track diseases, soil conditions, and plant health in precise agriculture in real time (Nezhad 2014). Nanosensors allow us to recognize diseases of plants prior to visible symptoms and thereby improve diseases and farm production and productivity (Rai and Ingle 2012). Dubas and Pimpan (2008) found that silver nanoparticles in a solution were prone to increased ammonia concentrations and caused a color variance from yellow to orange red and, finally, violet. This can be used to develop nanosensors to detect contamination from food, plants, and the environment as organic pollutants and microbial toxins (Dubertret et al. 2001). Fluorescent silicon nanoparticles, together with anticorps pathogens *Xanthomonas axonopodis* pv, are successfully observed. Bacterial spot conditions in tomatoes and peppers are caused by Vesicatoria (Yao et al. 2009).

Nanoparticles and nanolayers of copper oxide (CuO), which consist of nanowires, such as DNA molecules, polypeptides, fibrin proteins, and filamentous bacterial phages, have been synthesized using the sol gel and spray process, of which major sensing elements are composed. Since the surfaces of the nanowire are easily modified, almost every possible chemical or molecular biological detector unit can be used to decorate nanowires, making the wires autonomous.

Nanomaterials are extremely sensible, in real time and quantitatively to the nanowire conductance on their surface to express the chemical-binding activity. Ariffin et al. (2014) have used nanowire to detect cucumber mosaic virus and papaya ring spot virus as biosensor for this theory. Remote nanowires have been shown to be an excellent material for the development of nanoscale biosensors for further applications in plant health care, diagnosis of diseases, and environmental monitoring, for *Aspergillus niger* fungi detection. Nanowire biosensors are a category of nano biosensors which need more work to be used on a wide range of soil.

5 Use of Nano Carbon as a Sensor

In our research lab at nsnRc we work on Carbon Nano Material Selection for electrochemical sensors by measuring the electrochemical properties of different CNM from several different raw materials as a result of different pesticides. Electrochemical analysis already includes carbon as an electrode (Sharon 2008; Kareem et al. 2019). Residual pesticides are not just detrimental to human consumption in animals, but also less beneficial for crops. In order to provide the correct oxidation/reduction possible values for a specific analytic, it is important to prepare electrochemical cell having CNM as an electrode in this sensor. Nanosensors are small enough for traps and measures of individual proteins or little molecules that use carbon nanotubes or nano-cantilevers.

Many nanosensors operate by initiating enzyme reactions or by using nano-generated molecules called dendrimers to bind chemicals and proteins. Nanoparticles or nano surface elements trigger electric or chemical signal. For increased sensitivity and a lower response time due to nanosensors, pathogens and contaminant detection are possible.

5.1 Plant Disease Control Nano-Particles

Nano forms of carbon, gold, silica, and aluminum silicates are some of the nanoparticles in the field of managing plant diseases.

5.2 Nano Carbon, Silver, and Aluminosilicate

Nanosciences, in which completely different materials, new technologies, and new expectations exist for existing challenges concerning the regulation and use of agrochemicals, pesticides, and herbicides (Prasad et al. 2014, 2017). Focus is given to research in carbon nanoparticle production to reinforce, for example, natural fibers from coconuts, sisal, or nanoparticles containing or regulated by pesticides. Brazilian Agriculture Research Company (Embraga) is responsible for the production. Through developing agricultural nanotechnologies, Brazil is seeking to improve the quality of its exports. Most scientists focus on carbon nanotubes (CNTs). Carbon nanotubes are carbon allotropes whose cylindrical shapes are nanostructure. Such nanotubes are used in many ways, in particular in nanotechnology, electronics, and architecture. Frequently used as thermal conductors, such nanotubes contain special and surprisingly strong electrical properties.

Nanosilver nanoparticle for the bio-system is the most studied and used. Silver nanoparticles have a high surface area and a high proportion of the surface atoms relative to bulk gold. For a long time, significant inhibitory and bactericidal effects and a wide range of antimicrobial activities have been identified. Kim et al. (2008) reported that antifungal effectiveness of the *Sphaerotheca pannosa Var rosae* solution of colloidal nanosilver (1.5 nm average diameter) in powdery mildew. Greenhouse and outdoor roses are very prevalent and commonly known. It distorts the leaves, causes the leaves to curl, defoliates early, and reduces flowering. The chemical reaction of silver ion using physical method, reduction agent, and stabilizers was used to produce double capsulized nanosilver. In aqueous solution, they were very stable and very well dispersed. The 5000 ppm concentration nanosilver colloidal solution was diluted in 10 ppm of 500 kg and sprayed at an area of 3306 m^2 contaminated with rose powdery mildew. During 2 days, more than 95% of rose-powdery mildew was sprayed. Colloid nano silver is a well spread and stable solution for silver nanoparticle and is more resistant for bacteria and fungi, hence stronger fungicide. It is no wonder that "silver nano for the preservation and treatment of agricultural diseases" has been filed with maximum patents. Nanosilver was very common because of its control and identification of nanosilver as a pesticide (Anderson 2009).

Another such initiative is the use of active ingredient alumina silicate nanotubes. The benefit is that nanotubes sprayed from alumina silicate on plant surfaces are quickly collected in insect hair. The insects purposefully grow and eat nanotubes filled with pesticides.

5.3 Association Nanostructures Colloidal Forms for the Supply of Functional Ingredients

The ideal nanomaterials for nanodispersions and nano capsulation for the delivery of functional ingredients were found to be surfactant micelles, vesicles, bilayers, reverse micelles, and liquid crystals etc. Colloid is a stable system of small particulate matter that is scattered throughout a liquid. Colloids associated with polar, non-polar, and amphiphilic functional components have been used for many years to deliver. Nanoparticle size ranges from 5 to 100 nm in colloids. The biggest disadvantage is that colloids can dissociate spontaneously when diluted (Flanagan and Singh 2006; Chaudhari et al. 2020).

5.4 Nano-Emulsion Ingredients

Nanoemulsions can encapsulate functional ingredients in outlets that can reduce chemical degradation. It is a combination that doesn't blend easily two and more liquid (such as oil and water). The dispersed droplets have diameters of 500 nm or lower in nanoemulsion (Clements and Decker 2000; Youssef and Elamawi 2020).

6 Conclusion

Nanotechnology is the trending after biotechnology for groundbreaking research. However, in plant pathogen detection, the nanotechnological application is still in its infancy. Finding out new strategies to handle diseases would help further bio-nano technological research, particularly with regard to physiology, infection mechanisms, and disease diagnostics.

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