Handbook of AGRICULTURAL BIOTECHNOLOGY

Volume I
Nanopesticides

Edited By
Charles Oluwaseun Adetunji
Julius Kola Oloke

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Preface

The application of biopesticides is an alternative option that could ensure adequate agro-ecosystem functions and biodiversity, thereby enhancing agricultural production, the effective management of biotic and abiotic stressors, and the maintenance of animals, humans, and a healthy planet. Their effectiveness is due to their availability in larger quantities, eco-friendliness, and their ability to preserve beneficial microorganism and soil activity.

Biopesticides have been identified as a sustainable and permanent replacement to synthetic chemicals. Their application will go a long way toward preventing major challenges that confront sustainable agriculture, the actualization of global food production, and food security, helping to feed an ever-increasing population that is predicted to increase to nine billion by 2050. An interdisciplinary collaboration among policymakers, private sector, researchers, civil society, farmers, consumers, and environmentalists will foster an innovative pathway toward future sustainable agriculture and food systems that could ensure resilience, food security, and a healthy environment.

This book emphasizes the application of microencapsulation and nanoformulations technology that could enhance agricultural production while increasing stability and residual action of nanobiopesticides products, as well as improving their environmental sustainability and field application. A heavy emphasis is placed on the registration of nanobiopesticides with relevant stakeholders, plus the role of scientists and farmers, government, research institutes, industries, universities, agro-industries, and researchers. Additionally, relevant information is provided on the application of nanobiopesticides that could serve as an antibacterial antinematode, antimollusca, antimite, antirodent, and antiviral agent.

The chapters herein outline techniques for the characterization and structural elucidation of the biologically active constitutes that are found in plant materials and could be utilized in the fabrication of nanobiopesticdes. Relevant information is collected on some nanobiopesticides that could be applied as fumigants, which are used in the production of gas or vapor for effective destruction of pests in buildings or soil. Additionally, how to apply nanobiopesticides as biocides, disinfectants, and sanitizers is explained, too.

The book explains the application of some nanobiopesticides as ovicides that could kill eggs of insects and mites, as well as slimicides that could destroy slime-producing microorganisms, such as algae, bacteria, fungi, and slime molds. Other highlights include: a discussion on the application of nanobiopesticides for the rejuvenation of heavily contaminated environments (as well as their role in the mitigation of several abiotic stress); a demonstration of how nanobiopesticides derived from plants could be applied for effective management of pests and diseases in animal husbandry and fishery; and a collection of relevant information on patents, the commercialization of relevant plant-derived nanobiopesticides, and their social economic and industrial relevance.

This book is a useful resource for a diverse audience, including global leaders, industrialists, food industry professionals, agriculturists, agricultural microbiologists, plant pathologists, botanists, agricultural experts, microbiologists, biotechnologists, nanotechnologists, environmental microbiologists and microbial biotechnologists, investors, innovators, farmers, policy makers, extension workers, educators, researchers, and many in other interdisciplinary fields of science. It also serves as an educational resource manual and a project guide for undergraduate and postgraduate students, as well as for educational institutions that seek to carry out research in the field of agriculture and nanotechnology.

I offer my deepest appreciation to all the contributors who dedicated their time and efforts to make this book a success. Furthermore, I want thank my co-editors for their effort and dedication during this project. Moreover, I wish to gratefully acknowledge the suggestions, help, and support of Martin Scrivener and the Scrivener Publishing team.

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December, 2023

1

Application Nanobiopesticides Derived From Plants

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Abstract
The utilization of biopesticides for the management of agricultural pest and diseases has been carried for a long time, the incorporation of the vast knowledge gained from nanotechnology only commenced recently. The integration of nanomaterials in the development of biopesticides will, therefore, help in the mitigation of some of the challenges associated with the use of biopesticides alone, such as enhancing the overall efficiency, improved stability, effective delivery while limiting some of the negative effects. Nanotechnology has, therefore, provided the adoption of responsive, biodegradable, biocompatible, and intelligent materials for the fabrication of safe, green, and efficient pesticides. It has been indicated that the integration of nanotechnology to the existing biopesticides has the potential of ensuring the design and formulation of more reliable nanobiopesticides.

***Keywords*:** Nanobiopesticides, nanotechnology, biodegradable, biocompatible, biopesticides

1.1 Introduction

The role of nanotechnology in various areas of human endeavors, such as agriculture, medicine, industries, biotechnology among others cannot be overemphasized. The global population is rapidly increasing and the quest for quality food is increasing continually. The place of agriculture

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for the feeding of this population and environmental sustainability therefore becomes paramount. On yearly basis, it is reported that 25% of agricultural crops on global scale are destroyed by pests and diseases [1]. On this premise, the control and management of pest and diseases is necessary for improving agricultural yield and ensuring food safety and security. More recently, various approaches and pesticides formulations have been employed for the management of pesticides with a view to ensuring food security. Some of these include synthetic, chemical and biological measures. Basically, pesticides are grouped into different classes on the basis of their structures, compositions and targeted organisms into rodenticides, herbicides, bactericides, insecticides, fungicides, among others. The use of chemical pesticides has also been reported to posses it inherent limitation. These substances posses high toxicity to both pests and humans [2]. On global scale it has been documented that over 200,000 persons die on annual basis as a result of poisoning emerging from the use of chemical and synthetic agents. Some of the existing chemicals that have been employed in this regards have also showed some limitations as a result of challenges with efficient delivery mechanism, poor stability within the environment, low specificity, less biodegradability, as well as the high cost of formulation. The chemicals also contaminate the environment since they all pass through it polluting soils, water bodies and the atmosphere [3]. The workers in industries where these pesticides are produced are also prone to occupational hazards due to exposure to these toxic substances. Exposure to these pesticides occurs through the intake of food and water. In order to overcome the aforementioned limitations nanotechnology has shown to have promising results and prospects [4]. At present, nanotechnology has found relevance in various sectors and fields of humans in problem solving. The incorporation of nanopesticide to the area of agriculture has the potential of increasing the production of crop and improvement the mortality of pest. The use of nanobiopesticides gained remarkable attention in their usage against pests as a result of their minute sizes (1–100 nm), enhanced stability, large surface area, ease of application and cost effectiveness [5–7].

This book presents the synthesis and applications of nanobiopesticides in management of various agricultural pests and diseases causing microorganisms. Some of the areas of application covered in this word include their utilization as antirodents, antinematodes, antimites, antimollusca, antiviral agents, biocides, fumigants, ovicides, slimicides, disinfectants as well as their applications in the mitigation of various stresses associated with abiotic factors and the rejuvenation of various environment heavily polluted by numerous emerging contaminants.

1.2 Concept of Biopesticides

Biopesticides are pesticides of biological origin that are obtained majorly from natural substances or microorganisms. They are basically classified into three major groups which are the botanical biopesticides, the microbial based biopesticides and plants derived biopesticides. Biopesticides have gotten remarkable attention as alternative to the conventional agropesticides as a result of their unique features such as specificity in targeting, relatively fewer negative effects, ease of breaking down quickly and higher efficiency. There are several substances, which have been evaluated as potential biopesticides in recent times, which include oxymatrine (an alkaloid), stilbenes found in grape cane, olive oil mill, extracts of *Clitoria ternatea* and stains of *Talaromyces flavus*. The application of biopesticides does not have side effects of concern on the environment due to its eco-friendliness. There are specific products, which have been licensed as biopesticides, although they are still being investigated for any possible health effect [8].

1.3 Uniqueness of Nanobiopesticides

According to various scientific evidences, the emergence of nanotechnology has proven to be a highly reliable tool for the formulation of novel nanocomposites suitable for curbing pest and diseases in agriculture. The nanobiopesticides have outstanding superiority over the biopesticides as well as the other traditional approaches to pest mitigation. They posses unique biodegradability, environmental friendliness, rapid action, good result, easy discharge to plants, gentle release from the vector and remarkably high efficiency. The small sizes of the nanobiopesticides also make them useful carriers [9]. More recently, various nanobiopesticides have been documented to have high efficacies against different pests, such as *Bacillus sphacricus*, *Bacillus firmus*, *Trichoderma harzianum*, *Beauveria bassiana*, and *Bacillus thringicsis*. These groups of pesticide have also been reported not to have negative effects on the population of microorganisms in the environment. The nanobiopesticides are prepared through various routes, with the two major being: extraction of the bioactive compound with pesticidal effect and the blending it with nanomaterials prior to inserting it into a suitable polymeric materials which act as a base support, while in the other, the active pesticidal agent produces the metallic salt with the binded nanoparticles which then hemolysis and merges into the compatible vectors including liposomes, polymer, nanosphere, nanofibers, and micelles [1].

1.4 *In Vitro* Nanobiopesticides Assay

Nanobiopesticides could be evaluated against specific groups of pest so as to assess their efficacies prior to their large scale applications in farmlands. The nanobiopesticides could be produce through various active pesticide based compounds together with mixing of various nanoparticles such as silver oxide, zinc oxide and oxides of aluminum. The overall toxicity of the nanobiopesticide is checked through the use of minimum inhibitory contents which employs the diffusion method based on agar well. It involves the coating of filter paper with the outer layer of nanobiopesticides as well as oral introduction to the targeted pest. Final measurement is done on the concentration of the pest that are dead and those that are alive within an interval of 40 days [2].

1.5 *In Vivo* Treatment with Nanobiofungicides

Nanobiofungicides can be introduced into plants in the right doses so as to ensure their protection from seasonal infections. The use of LC50 and LC90 help in the detection of the specific insects, larvae and attacks by bee. The nanobiopesticides are also used in changing environments like humidity, temperature and stresses from the environment. Under such conditions, the nanobiopesticides are applied directly as sprays in protecting the plants from attack by pests. The application of nanobiopesticides has therefore become the most efficient approach for the control of attacks by pests that transmit diseases [9].

1.6 Conclusion

There is increasing destruction of a large component of global agricultural yield due to the activities of pests. Recent studies revealed the various side effects associated with the use of chemical pesticides such neurotoxicity, Parkinson's disease, endocrine disruption, malignancies and obesity [10–19]. The emergence of nanobiopesticides has been identified as one of the most remarkable breakthrough in the field of nanotechnology. Nanobiopesticides are ecofriendly, benign with unique biodegradation potential.

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2

Application of Plant-Based Nanobiopesticides That Could Be Applied as Fumigants

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Abstract

Production of crops and farm products has reduced drastically over the years. This has been traced down to the infestation of pests and insects on the crops right on the field. Most of these pests are called plant pathogens. However, several methods have been utilized to eradicate or kill these pests or insects on the field; this is done so as to improve the production of crop. One of those methods includes the utilization of synthetic pesticides. The use of chemical pesticides was however banned in 2015, despite the fact that it shows good pesticidal activity. Chemical pesticides became illicit as a result of the negative impact they exert on both the environment and human health. Production of pesticides from natural substances or microorganisms is called biopesticides. The use biopesticides then replace chemical pesticides due to its minimal adverse effects, high efficacy and potential target specificity. Moreover, nanotechnology was integrated to the production of biopesticides, which give rise to nanobiopesticides. Nanobiopesticides are appealing for usage because of their properties, such as greater solubility, steadiness, huge surface-area-to-volume proportion, mobility, enhanced efficiency, decreased toxicity, and small size. Because of their low toxicity, they are highly recommended. These nanobiopesticides can be synthesized through various ways and can also be

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applied in pest management. The full knowledge of the application of plant-based nanobiopesticides as fumigant has not been fully known, but few of the applications are discussed in this study.

Keywords: Nanobiopesticides, fumigants, nanotechnology, pesticides, biopesticides, biodegradability, pests, ecofriendly

2.1 Introduction

Lack of foods has been a major concerned in the world today, as the population is growing steadily to about 7.7 billion. This occurred as a result of the natural challenges (both living and nonliving), which include pests, infections, and weeds [1]. There are over 65,000 types of pests recorded in time past. These pests are also referred to as plant pathogens and they include fungi, weeds and arthropods [2]. It has been estimated that pest poses a lot of losses on crops. These losses are estimated as thus; 10%, 20%, 25%, 30%, 35%, and 50% losses in wheat crops, sugar, rice, pulses, oil seeds and cotton respectively. About USD 2000 billion has however been estimated to the crops loss annually which originated from pests and diseases [1]. However, this problem has paved way to a challenge in science, which is to improve the crops against pests without affecting the crop yields. Synthetic pesticides have been used to enhance the inhibition of pests for a good crop production [3] and they have been of great interest due to their large scope of usefulness in the control of insects and their potential to eliminate the presence of pests in agricultural ecosystem. Biopesticides are derived from plants and the secondary metabolites produced by plants, which include glycoalkaloids, organic acids, and alkaloids. All these have been identified as a potential origin of plant effecting pests [4–15].

Pesticides are divided into different groups and they include pesticides produced from chemical compounds, pesticides produced from biological activities (biopesticides), synthetic pesticide, pesticides synthesized from microbes, plant-incorporated pesticides, and biochemical pesticides. Figure 2.1 shows the significance of nanotechnology in the production of nano-based biopesticides [35]. Different kinds of seeds and weeds are treated and controlled through the use of chemical pesticides. They can be delivered to plants directly or indirectly. Indirect delivery is done by spraying chemicals on plants. The utilization of synthetic pesticides was, however, banned in 2015, despite the fact that it shows good pesticidal activity. Chemical pesticides became illicit as a result of the negative impacts they exert on both the environment and human health. A good example is methyl bromide. Methyl bromide is a good chemical pesticide that has been used for over 4 decades to treat many crops such as strawberry, melon seeds, all varieties of peppers and tomatoes against pests, nematodes, and soil pathogens. However, methyl bromide contributes negativity to the depletion of ozone layer and this prompted to its ban according to the regulation given by Protocol by Montreal.

Likewise, different synthetic compounds utilized as pesticides, for example, dazomet and chloropicrin have additionally been suspended; this is because of the antagonistic impact on food and human well-being [16]. Insecticides produced from natural substances or microorganisms are named biological pesticides or biopesticides. Three different types of biopesticides exist, and they include plant-incorporated protectants, microbial biopesticides, and botanical pesticides [17]. Characteristics of biopesticides include minimal adverse effects, capacity to disintegrate fast, high efficacy, and potential target specificity. These characteristics, however, paved way for biopesticides to serve as an alternative to conventional insecticidal methods. A lot of substances that have been investigated as biopesticides include the fractions isolated from *Clitoria ternatea*, an

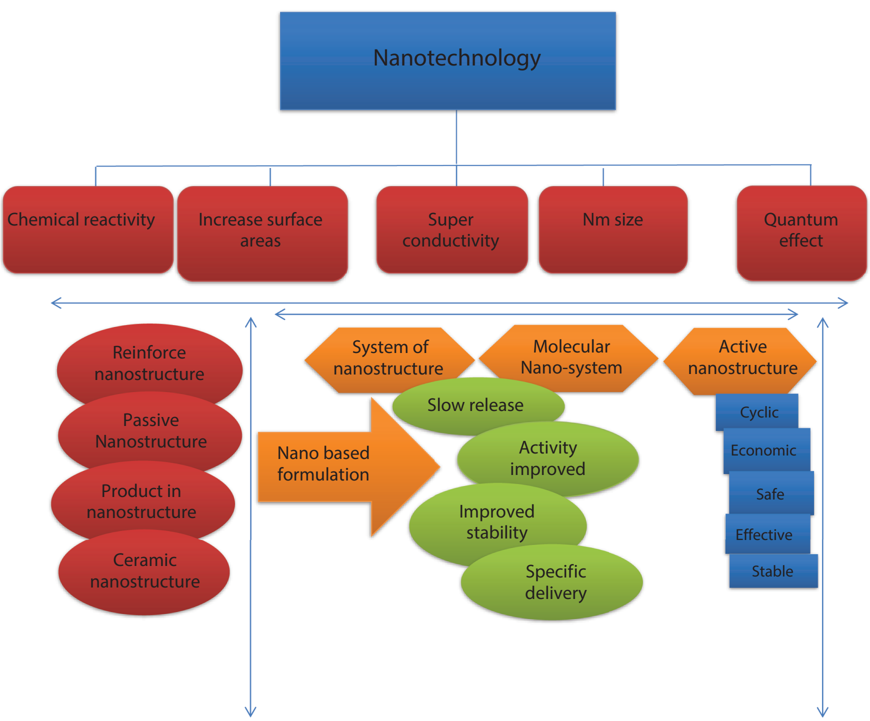

Figure 2.1 Significance of nanotechnology in the production of nano-based biopesticides. Source: Lade *et al.* [35].

alkaloid component called oxymatrine, stilbenes in grape cane, olive mill oil, and *T. flavus* [18]. Due to the negative influence biopesticides have on the human health status, it is advisable for its administration to be done with caution [19].

Recently, a novel field called nanotechnology has gained special attention due to its application in multidisciplines. These include parasitology discipline, agriculture field, pest management, and pharmacology field [20]. Nanoparticles (NPs), a rapidly expanding area of nanotechnology, provide solutions to lots of natural challenges as a result of their cost effectiveness, tiny size (1–100 nm), wide surface area, and cost effectiveness. It has been established that novel nanocomposites can be produced using an effective equipment nanotechnology. This is done so as to prevent crops from pest infestation and also to enhance different crops varieties [21].

2.2 Types of Biopesticides

Biopesticides exist in various kinds and are characterized in accordance to the various factors, which include origin of extractions and sorts of atoms utilized for arrangement/preparation [22]. The different types of biopesticides are explained below.

2.2.1 Microbial Pesticides

Different organisms have been utilized for the synthesis of microbial pesticides. Microbial pesticide affects both entomopathogenic nematodes and distinct pest species. Bioinsecticides are known as the compounds or molecules that target the insects that affect crops, while bioherbicides are pesticides that have influence over weeds via microbes, like fungi. A wide range of research carried out on microbial pesticides has resulted to the detection of a huge quantity of biopesticides, and this has also created a great path for their marketability [22].

The effective utilization of *Bacillus thuringiensis* and a few species of other microbes driven to the disclosure of numerous modern species and strains of microbes, and their profitable poisons and destructiveness components that might be a benefit for the biopesticide business, and a few of these have been deciphered into saleable items as well [23]. Significant species of bacterial entomopathogens involve *Pseudomonas* sp., *Chromobacterium* sp., *Yersinia* sp., etc., whereas fungi contain the following *Paecilomyces* sp., *Beauveria* sp., *Lecanicillium* sp., *Metarhizium* sp., *Hirsutella* sp., *Verticillium* sp., and so on [24]. Other crucial makers of pesticides synthesized from microbes include *baculoviruses* which are species explicit and their infectious activity is related with the crystal-clear impediment bodies which are dynamic on pests (*Lepidopteran* caterpillars) [24].

2.2.2 Biochemical Pesticides

The normal happening products, which are utilized to manage pests via nonharmful instrument are called biochemical pesticides, although pesticides produced from chemical synthesis utilize engineered atoms that specifically destroy insects and pests. The characterization of biochemical pesticides into distinctive types depends on their function in the management of invasions of pests and insects by exploiting pheromones (semichemicals), natural pests' growth regulator or plant fractions/oils. Figure 2.2 shows different categories of biopesticide [36].

2.2.3 Insect Pheromones

Insect pheromones are synthetic compounds made by pests and insects, which are mirrored for utility in managing pests within the coordinate's pest management programs. These synthetic compounds are viable in disturbing pests mating to avoid the aim of mating, hence decreasing the quantity of pests offspring. The pests used in this mechanism behave as allocators of pheromones that had the chance to be bewildered because of the existence of semiochemical flumes dispersed in the environment. Insect semiochemicals are not genuine "insecticides" because they do not destroy pests but impact their olfactory structure, which influence their conduct [25]. An accurate record of the method of activity of pheromones was described by Ujváry [23]. Summarily, the receiving wires (antennae) of the seeing pests accumulate pheromones on the surface, which is further dispersed to the inner parts of sensilla via minute openings within the cuticula. When they entered, they are exchanged via the polar sensillum to the sensory receptor layers by semiochemical binding proteins. Hence, the semiochemical binds to a particular protein receptor, which changes the synthetic compounds signs to an increased electric signs by a second courier structure associated with neuronal apparatus [26].

2.2.4 Essential Oils and Plant-Based Extracts

Plant-based fractions and essential oils have developed as promising insect pest management options in contrast to chemical insecticides in recent years. Because they are generated out of vegetations and consist of a variety of active compounds, these insecticides are naturally occurring insecticides [27].

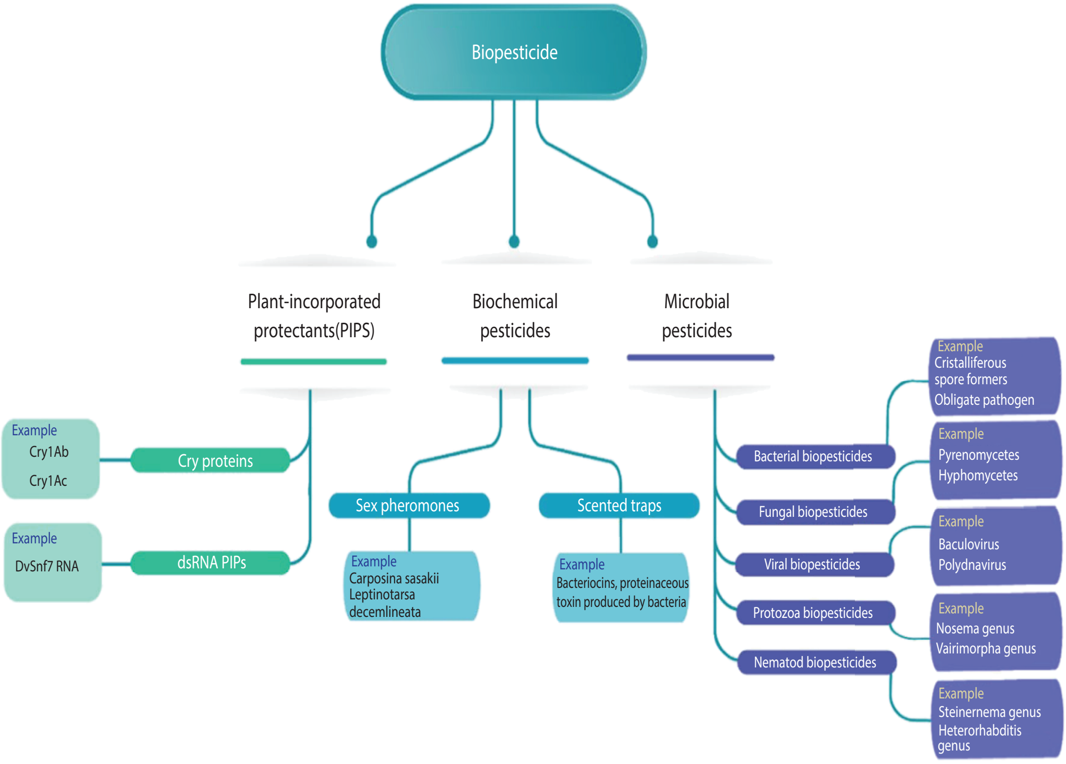

Figure 2.2 Different categories of biopesticide. Source: Abdollahdokht *et al.* [36].