CHAPTER 1

Introduction:
Potential of Botanicals and Microorganisms as Biopesticides

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Abstract
Current agricultural practices depend heavily on chemical inputs (such as fertilizers, pesticides, herbicides among others) which cause a deleterious effect on the nutritional value of farm product and health of farm workers and consumers. The increasing awareness of health challenges as a result of consumption of poor quality crops has led to a quest for new and improved technologies of improving both the quantity and quality of crop without jeopardizing human health. A reliable alternative to the use of chemical inputs are botanicals and microbial inoculants that can act as biofertilizers, bioherbicide, biopesticides, and biocontrol agents. Plants and microorganisms are the major sources of biopesticides due to the high components of bioactive compounds and antimicrobial agents. Biopesticides are biological control or natural pest management agents that are based on beneficial microorganisms (bacteria, fungi, viruses and protozoa, beneficial nematodes i.e. entomopathogenic nematodes, parasitoids, predators) and biologically-based active ingredients such as botanical products and pheromones. Many of these biological agents and their products (such as *Bacillus thuringiensis* (*Bt*-toxin), *Azadirachta indica* (neem plant extract) are used against various plant pathogens and pests in Nigeria, Kenya, Botswana, Ghana and other African countries. Biopesticides are applied in the same manner as chemical pesticides like gammalin, actellic dusts and DDT powder. Although, the synthetic pesticides have been found to have positive effect on diseases and pests, but harmful effect on man and the ecosystem.
Keywords: biopesticides, botanical pesticides, microbial pesticides, indigenous knowledge, human health

Introduction
The use of chemical fungicides is considered as the most effective method of plant disease management and often practised worldwide. However, repeated use of certain chemical

fungicides has led to the appearance of fungicide- resistant pathotypes of several pathogens. In recent years, there has been considerable pressure by consumers to reduce or eliminate chemical fungicides in food products. The use of chemical fungicides for the management of plant diseases has its limitations due to their carcinogenic, teratogenic properties, high and acute residual toxicity, hormonal imbalance, slow and long degradation period, environmental pollution and deterioration of food quality and adverse effects on human health (Brent and Hollomon, 1998; Dubey *et al.*, 2007; Kumar *et al.* 2007). Their uninterrupted and indiscriminate use has not only led to the development of resistant strains, but the accumulation of toxic residues on food grains used for human consumption has also led to health problems (Sharma and Meshram, 2006).
Agrochemicals are commonly used in agricultural production to control or prevent diseases, pests and weeds in order to maintain high quality of agricultural products and eliminate or reduce yield losses (Alori and Babalola, 2018). With this, food is produced at reduced costs and farmers therefore get higher profit from their farm but serious concerns were being raised about health risks resulting from residues in drinking water and food and from occupational exposure (Alori and Fawole, 2017). Suyal *et al.* (2016) reiterated that heavy doses of chemical fertilizer, although leading to self-reliance in food production, causes harmful impacts on living organisms and also depreciate the environment. The chemical contaminates the food produced and goes further to alter the normal body functions of the consumer (Sayre, 2009). Baker *et al.* (2002), reported 75% of pesticide residues in conventionally grown produce. Water supplies are polluted by toxic insecticides, herbicides, and chemical fertilizers used (Alori and Fawole, 2017). Plants and microorganisms are the major sources of biopesticides due to the high components of bioactive compounds and antimicrobial agents (Nefzi *et al.*, 2016).

Numerous studies have documented the antifungal and antibacterial effects of extracts and oils from plants (Canillac and Mourey 2001, Adejumo and Langenkämper, 2010; Adejumo, 2012 and Orole *et al.* 2016). The examination of indigenous local herbs and plant materials has also been reported from different parts of the world. Higher plants contain essential oils and a wide spectrum of secondary metabolites such as phenols, flavonoids, quinones, tannins, alkaloids, saponins and sterols. Such plant-derived chemicals may be exploited for their different biological properties, because of their natural/plant origin, they are biodegradable and do not usually leave toxic residues or by-products. Medicinal plants constitute an effective source of both traditional and modern medicine (Abd El-Ghani, 2016). Plants have been shown to have genuine utility and about 80% of the rural population depends on them as primary health care (Akinyemi, 2000). Plants have been used as sources of remedies for the treatment of many diseases since ancient times and people of all continents especially Africa have this old tradition. Despite the remarkable progress in synthetic organic medicinal products of the twentieth century, over 25% of the prescribed medicines in industrialized countries are derived directly or indirectly from plants (Newman *et al.*, 2000). However, plants used in traditional medicine are still under-studied (Kirby, 1996). In developing countries, notably in West Africa, new drugs are not often affordable. Thus, up to 80% of the population uses medicinal plants as remedies (Kirby, 1996; Hostellmann and Marston, 2002).

Botanical medicine has been used throughout history similar to the way modern pharmaceuticals are used today (to improve human health). Fossil evidence suggests that plants were used medicinally in prehistoric times (Robert, 1976). Although, the first use of plant-derived pharmaceuticals may be difficult to pinpoint, the use of botanicals for human health is the basis for the modern pharmaceutical industry (Newman and Cragg, 2007 and Raskin *et al.*, 2002). Botanicals and the purification of their active ingredients have played a significant role in the history of mankind. The purification of an early botanical from opium poppy (*Papaver somniferum*) was described in great detail in 1806 in a report summarizing 57 studies (Boussel *et al.*, 1982). The botanical was very effective for pain and insomnia, leading to a world social crisis when its addictive nature was realized in the mid 19th century (Boussel *et al.*, 1982).

For botanicals to be reliable for research purposes and consumer products, they must be standardized with sufficient quality controls to ensure consistent composition, safety, and potency. This includes uniform cultivation of source plants with controls to monitor for contamination from other species, pesticides, and environmental toxins. The active components of botanicals must be identified by activity-guided fractionation with the use of *in vitro* assays that require little test material, followed by validation *in vivo*. Concentrations of active compounds within the botanicals can then be accurately measured to ensure the delivery of a dependable dose in the final product. The use of bioenhancing agents may be considered for compounds with poor bioavailability. Standardization of botanical therapeutics can only be achieved when the active compounds are identified and biological activity is confirmed, thus ensuring a consistent product.

A careful selection of microbes and intelligent design of test assays are the key steps in developing new technologies for effective utilization of microorganisms for sustainable agriculture, environmental protection, and human and animal health. Several microbial applications are widely known in solving major agricultural (crop productivity, plant health protection, and soil health maintenance) and environmental issues (bioremediation of soil and water from organic and inorganic pollutants). Wastewater treatment and recycling of agricultural and industrial wastes are other important uses of microbial technology. It is expected that microbes in combination with developments in electronics, software, digital imaging, and nanotechnology will play a significant role in solving global problems of the twenty-first century, including climate change. These advances are expected to enhance sustainability of agriculture and the environment.

The global challenge is to secure high and quality yields and to make agricultural produce environmentally compatible. Eco-friendly alternative has been claimed to be the need of the hour, despite many years of effective control by the conventional synthetic agrochemicals due to human health and environmental concerns threatening its continued use. Therefore, there is a need to develop biopesticides which are effective, biodegradable and do not leave any harmful effect on environment (Nicholson, 2007).

What are Biopesticides?
Biopesticides are defined as compounds that are derived from natural organisms or substances such as animals, plants, bacteria, and certain minerals, including their genes or metabolites to manage agricultural pests by means of specific biological effects rather than as broader chemical pesticides (Sporleder *et al.*, 2013, https://www.epa.gov/ingredients-used-pesticide-products/what-are-biopesticides). They are products and by-products of naturally occurring substances such as insects, nematodes, microorganisms, plants as well as semiochemicals (Gasic and Tanovic, 2013). According to FAO definition, biopesticides include biocontrol agents that are passive agents, in contrast to biocontrol agents that actively seek out the pest, such as parasitoids, predators, and many species of entomopathogenic nematodes. Biopesticides differ in their modes of action from conventional chemical pesticide considerably; their modes of action are almost always specific. The rationale behind replacing conventional pesticides with biopesticides is that the latter are more likely to be selective and biodegradable" (http://www.fao.org/biotech/spec-term-n.asp?id_glo¼ 4875&id_lang¼TERMS_E). Based on the nature and origin of the active ingredients, biopesticides fall into several categories such as botanicals, antagonists, compost teas, growth promoters, predators and pheromones (Semeniuc *et al.*, 2017). Using biopesticides efficiently therefore requires specific user knowledge on the agent and the target pest for optimizing application time, field rates, and application intervals (Sporleder *et al.*, 2013).

Classification of Biopesticides
Biopesticides can be classified as three major classes as follow:

- **Biochemical pesticides**: pesticides based on naturally occurring substances that control pests by non-toxic mechanisms, in contrast to chemical pesticides that contain synthetic molecules that directly kill or inactivates the pest. Biochemical pesticides fall into different biologically functional classes, including plant extracts, substances that interfere with mating, such as insect sex pheromones, as well as various scented plant extracts that attract insect pests to traps. Botanical pesticides that have already been commercialized include neem, pyrethrum, cotton and tobacco. Other sources of botanical pesticides include garlic, euphorbia, citrus, pepper among others (Lengai and Muthomi, 2018). According to Ragunath *et al.*, 2014, Biochemical pest control agents include four (4) general biologically functional classes:

1. **Semiochemicals**: These are chemicals emitted by plants or animals that modify the behaviour of receptor organisms of like or different kinds. They include pheromones, allomones, and kairomones. Pheromones are substances emitted by a member of one species that modify the behaviour of others within the same species. Allomones are chemicals emitted by one species that modify the behaviour of a different species to the benefit of the emitting species. Kairomones are chemicals emitted by one species that modify the behaviour of a different species to the benefit of the receptor species.
2. **Hormones**: These are biochemical agents synthesized in one part of an organism and translocated to another where they have controlling, behavioural, or regulating effect.
3. **Natural Plant Regulators**: These are chemicals produced by plants that have toxic, inhibitory, stimulatory, or other modifying effects on the same or other species of plants. Some of these aretermed "plant hormones" or "phytohormones."
4. **Enzymes**: In this regard, enzymes are protein molecules, which are the instrument for expression for gene action and catalyze biochemical reactions.

- **Microbial pesticides and other entomopathogens**: pesticides that contain microorganisms, like bacteria, fungi, or virus or protozoan, which attack specific pest species, or entomopathogenic nematodes as active ingredients. Microbial pesticides can control different kinds of pests, although each separate active ingredient is relatively specific for its target pest(s). These include biofungicides (*Trichoderma*), bioherbicides (*Phytopthora*) and bioinsecticides (*Bacillus thuringiensis*), the most widely used microbial pesticides. Each strain of this bacterium produces a different mix of proteins and, specifically, kills one or a few related species of insect larvae. While some Bt's control moth larvae found on plants, other Bt's are specific for larvae of flies and mosquitoes. The target insect species are determined by whether the particular Bt produces a protein that can bind to a larval gut receptor, thereby causing the insect larvae to starve. Biopesticides exhibit different modes of action against pathogens such as hyperparasitism, competition, lysis and predation. Microbial biopesticides include bacteria species such as *Pseudomonas*, *Bacillus, Xanthomonas, Rahnella and Serratia* or fungi such as *Trichoderma, Verticillium* and *Beauveria* species (Kachhawa, 2017). Plant growth promoting *rhizobacteria* (PGPR) protect plants from biotic and abiotic stresses and they also enhance plant growth and enhance formation of root hairs. The most common species of PGPR include *Agrobacterium, Ensifer, Microbacterium, Bacillus, Rhizobium, Pseudomonas, Chryseobacterion and Rhodococcus* (Abbamondi *et al.*, 2016). They colonize the environment around the plant roots, fix nitrogen, increase phosphate solubilisation and result in general increase in plant yield. Species of *Pseudomonas* and *Bacillus* have been used as biofertilizers with reports showing increase in plant growth, yield and phosphorous and zinc content in fruits and soils. Natural enemies including predators, pathogens and some insects are also used as biopesticides in management of insect pests. Parasitoids, wasps, beetles, lace wings, bugs and lady birds are used in management of destructive pests such as boll worms (*Helicoverpa armigera*) in important crops such as cotton. Compost teas are filtrates of compost extracts and are similarly used as biopesticides (Ghorbani *et al.*, 2005). Species of *Trichoderma, Bacillus*, *Pseudomonas*, *Beauveria* have been commercialized as microbial pesticides (Lengai and Muthomi, 2018).

- **Plant-Incorporated Protectants (PIPs)**:
  Plant-Incorporated-Protectants (PIPs). This class of biopesticides consists of genetically modified plants (or insecticidal transgenic crops) that produce chemicals (pesticides) that act as protection against pest infestation. In general, PIPs are typically extracted from the transgenes (protein-based cytotoxins) of the insect pathogenic bacteria *Bacillus thuringiensis* (Bt) (All, 2017; http://www.epa.gov/opp00001/biopesticides/). In principle, PIPs, also termed semi-chemical pesticides, are also widely used for pest control. This is due to the minimal impact these class of biopesticides exert on humans and the environment (All, 2017, Walia *et al.*, 2017). Consequently, significant research and scientific resources are dedicated to PIPs as natural pest control agents.

Advantages of Biopesticides

Some of the benefits of botanical and microbial biopesticides over synthetic pesticides include the following:

- Lack of polluting residues: The residues of biopesticides are not toxic to humans or other animals, and they can be applied even when a crop is almost ready for harvest. They are much less harmful to the ecosystem than the synthetic pesticides. The organisms (i.e. biocontrol agents) are essentially nontoxic and non pathogenic to wild life, humans, and other organisms not closely related to the target pest. They pose fewer risks than conventional pesticides. The safety offered by microbial insecticides is their greatest strength (Usta, 2013).
- High level of safety to non-target organisms: The toxic action of microbial insecticides (biopesticides) is often specific to a single group or species of insects. This specificity means that most biopesticides do not directly affect beneficial insects (including

predators or parasites of pests) in treated areas. Biopesticides generally affect only the target pest and closely related organisms, in contrast to broad spectrum conventional pesticides that may affect organisms as different as birds, insects and mammals. Biopesticides are usually inherently less toxic than conventional pesticides.

- In some cases, pathogenic microorganism can become established in a pest population or its habitat. They provide control during subsequent pest generations or seasons.
- Biopesticides help to reduce the risk of pest resistance. There is evolution of resistance in the pest population to most of the synthetic pesticides used in combating plant. Plant pests and diseases.
- Biopesticides often are effective in very small quantities and often decompose quickly, resulting in lower exposures and largely avoiding the pollution problems caused by conventional pesticides.
- When used as a component of Integrated Pest Management (IPM) programs, biopesticides can greatly reduce the use of conventional pesticides, while crop yields remain high.
- It requires less data and less time to register than conventional pesticides.
- Most microbial pesticides replicate in their target hosts and persist in the environment due to horizontal and vertical transmission, which may cause long-term suppression of pest populations even without repeating the application.
- The use of biopesticides is markedly safer for the environment and users, and more sustainable than the application of chemicals, hence their use as alternatives to chemical pesticides as components in Integrated Pest Management (IPM) strategies.

Biopesticides in Sustainable Agricultural Production

The availability of source materials of biopesticides makes them inexpensive to attain since they are found within the natural environment, and some of them are used for other purposes like food and feed. Biopesticides are safe products both for the applicant and the consumer since they have no toxicity (Damalas and Koutroubas, 2015). Biopesticides can therefore be suitably incorporated in integrated pest management (IPM), which helps to reduce the amount of chemical pesticides in management of crop pests. Natural products decompose quickly which makes them safer for use in the environment. Pesticides from natural sources have very short re-entry intervals which guarantee safety for the applicant. Biopesticides are also used in the decontamination of agricultural soils through introduction of important microbial species. They provide advantages as safe environment and healthy food for human consumption, however, there are factors that limit their full adoption as pest and disease management options (Ghorbani *et al.*, 2005).

Biopesticides of botanical Origin

Botanical pesticides are first-generation pesticides being used in traditional agriculture for more than a century. These are higher plant origin pesticides which can directly or indirectly kill or reduce the target pest population. They serve as important alternatives to minimize the use of synthetic pesticides, because they possess an array of properties including toxicity to the pest, repellency, antifeedancy and insect growth regulatory activities against pests of agricultural importance.

They can either be plant extracts or essential oils. They are obtained from plants parts such as leaves, barks, flowers, roots, rhizomes, bulbs, seeds, cloves or fruits which are either fresh or dried. Dried plant parts are preferred as this reduces water concentration resulting in higher yield of active ingredient (Chougule and Andoji, 2016). The active compounds in plants include phenols, quinones, alkaloids, steroids, terpenes, alcohols and saponins (Mizubuti *et al.,* 2007). Different plant families have varied antimicrobial bioactive compounds which include oil components such as α- and β-phillandrene, limonene, camphor, linalool, β-caryophyellene and linalyl acetate depending on the plant family (Ali *et al.,* 2017). The most common and already commercialized botanical pesticides are derived from neem (*Azadirach*ta *indica*), pyrethrum (*Chrysanthemum cinerariifolium*), sabadilla (*Schoenocaulon officinale*) and tobacco (*Nicotiana tabacum*).

Advantages of botanicals over synthetic pesticides

Bhagat *et al.*, 2014 and Prakash *et al.*, 2014 highlighted the advantages of botanicals over synthetic pesticides are as follows:

- Possess low mammalian toxicity and thus constitute least/no health hazards and environmental pollution
- Practically, no risk of developing pest resistance to these products, when used in natural forms
- Less hazards to non target organisms and pest resurgence
- Promote sustainable agriculture: It does not cause ill effect on the crop plants, soil health and environment. No adverse effect on plant growth, seed viability and cooking quality.
- Reduce crop losses: Several plant diseases/plant pathogens can be effectively managed by reducing disease incidence and related losses in the crop plants.
- Eco-friendly and organic farming: It is eco-friendly in nature, does not cause ecological imbalance and suitably fit in any agroecosystem. It suitably fits in the organic farming system.
- Biodegradable: It rapidly degrades under the exposure of sunlight.
- Integrated disease management: It can be suitably incorporated in the framework of integrated disease management.

- Cheaper and easily available: It is relatively cheaper than conventional chemical fungicides and easily available. Thousand seventy-five species of higher plants have been found to possess pesticidal property against insects, mites, nematodes, molluscs, birds and rodent pests of agricultural importance. Some of the botanicals like neem, bel, ocimum, senwar, pyrethrum, tobacco, karanj, mahua, cymbopogon and sweet flag have already attained the status of potential pesticides of plant origin against field pests including phytonematodes and plant mites and also against insect pests in storage ecosystems.

Microorganisms as Sources of Biopesticides

Microorganism-based biocontrol agents form the bulk of commercialized biopesticides and they include bacteria, viruses, fungi, nematodes and protozoa. Lengai and Muthomi, 2018 reported that up to 175 reported microbial based biopesticide active agents have been used in the management of pathogens, weeds, insects and nematodes. Majority of the microbial biopesticides are used to manage soil borne pathogens (Vinale *et al.*, 2008). Bacterial species that have been utilised as biopesticides include *Bacillus, Pseudomonas, Burkholderia, Xanthomonas, Enterobacter, Streptomyces, Serratia* and these are either obligate facultative or crystalliferous. Fungi used as biopesticides include species of *Trichoderma, Beauveria, Metarhizium, Paecilomyces, Fusarium, Pythium, Penicillim and Verticillium. Steinernama and Heterarhabditis* are nematode species used to make biopesticides (Kachhawa, 2017). The mechanisms of action exhibited by microorganisms against plant pathogens include hyperparasitism, competition, secretion of volatile compounds, antibiosis and parasitism. The rhizosphere is usually concentrated with various classes of important microorganisms. Other rich sources of microorganisms include hay, manure, cow shed, as well as straw.

Modes of Action of Biopesticides

Each type of biopesticide exhibits varied modes of action.

Microbial pesticides act on pathogens by antagonism, hyper parasitism, antibiosis and predation (Lengai and Muthomi, 2018). Hyperparasitism has been found to be one of the most reported modes of action on many biocontrol agents. The antagonist kills the pathogen or its propagules, while some attack the sclerotia or the hypha of the fungal pathogen. *Pasteuria penetrans* is a biocontrol agent that parasitizes on root-knot nematodes *of Meloidogyne spp*., while species of genus *Trichoderma* exhibit predation mode of action by producing enzymes that directly kill cell walls of pathogens and colonize the environment therein.

By antibiosis mechanism, some microorganisms produce compounds that kill other microorganisms, mostly common with the following bacterial species: *Pseudomonas, Agrobacterium, Bacillus, Burkholderia, Pantoea* as well as fungus *Trichoderma spp*. Sufficient quantities of antibiotics need to be produced for enhanced biocontrol. Some microbial species like *Bacillus cereus* produce multiple compounds that could suppress more than two pathogens making it to be effective in crop disease management.

Other microorganisms like *Lysobacter and Myxobacteria* produce lytic enzymes which hydrolyze compounds leading to suppression of pathogen. *Beauveria bassiana* inhibits chitin development in insects by conidia attaching to the body of insects. After germination, the hypha penetrates through the cuticle and grows throughout the insect body and eventually killing it (Prasad and Syed, 2010).

Botanical pesticides inhibit growth of pathogens, modify their cellular structures and morphology and exhibit neurotoxicity on insects. They also repel insects, suppress oviposition and feeding. Ngegba *et al* (2018) reported that extracts of neem (*Azadirachta indica*) and Mexican sunflower (*Tithonia diversifolia*) inhibited growth of rotting disease pathogens of tomato, *Aspergillus niger, Fusarium oxysporum and Geotrichum candidium* by up to 100%.

Semiochemicals such as female sex pheromones are used to lure the male insect pests which are then sterilized thereby decreasing their effectiveness. Upon mating with the sterile male insects, the females lay unfertilized eggs thereby reducing harmful insect populations. Some bioactive compounds cause partitioning of fungal cell membranes making them permeable leading to leakage of cell contents, while others cause separation of cytoplasmic membrane that leads to damage of the intracellular components and swelling of cells and eventual death. The compounds allicin in garlic (*Allium sativum*) bulbs cause suffocation of the pest due to effects on receptors of neurotransmitters (Baidoo and Mochiah, 2016).

Predators mainly kill the prey through parasitization or injection of toxic substances which eventually kill the prey. Natural enemies predate on insect pests which balances their population in the ecosystem. The mechanisms used by predators to lure insects include scents and other attractants. Some of these scents, called pheromones, have been commercialized and are being used in the management of important crop pests such as *Tuta absoluta*.

Conclusion

Synthetic pesticides are considered more effective than biopesticides in managing crop pests. Their effectiveness sometimes has nonetheless no much significance in managing a particular population of pest as would the biopesticides. Our world needs effective, environmentally smart agricultural technologies that are safe for people and protect our natural resources (Parliman, 2001). Biopesticides are revolutionizing farming practices around the world, improving productivity for organic crops, making conventional harvests safer, reducing the environmental impact of agriculture and ensuring that consumers are not ingesting chemicals on their food (Business Daily, 2013). It has been reported that biopesticides in other instances perform better than synthetic pesticides when applied in the right regimes, concentrations and appropriate frequencies (Shah *et al.*, 2013).

Sustainable farming starts with a healthy soil, which results in a healthy plant. The healthy soil concept is now being trumpeted everywhere and being adopted by conventional farmers. Biopesticides play a critical role in ensuring optimal soil health as the foundation for sustainable agriculture and food and production (Maksymiv, 2015). Conventional farmers also find benefits from the innovations in biopesticides, especially around harvest time and they are increasingly adopting biopesticides to eliminate synthetic chemical residues on the crops they grow. Farmers can spray biopesticides right up to harvest and then export without any residue issues (Damalas and Koutroubas, 2015). While traditional chemical pesticides often lose their efficiency as pests build up resistance, biopesticides have managed to thwart the natural ability of insects to adapt and develop resistance, leading to healthier crops, better food, wine and cannabis products for consumers and a cleaner environment (Plata-Rueda *et al.*, 2017).

Ragunath *et al.*, 2014 reported that Biopesticides is a key components of integrated pest management (IPM) programs, which is receiving much practical attention as a means to reduce the load of synthetic chemical products for controlling plant diseases. In most cropping systems, biological pesticides should not necessarily be viewed as wholesale replacements for chemical control of plant pests and diseases, but rather as a growing category of efficacious supplements that can be used as rotation agents to retard the onset of resistance to chemical pesticides and improve sustainability. In organic cropping systems, biopesticides can represent valuable tools that further supplement the rich collection of cultural practices that ensure against crop loss to diseases.

According to Lengai and Muthomi (2018), despite the many challenges facing the adoption of biopesticides, they still remain suitable alternatives to conventional pesticides. The use of synthetic chemicals has raised numerous concerns due to their negative effects on the environmental, human health, natural enemies and ecosystem balance. Some of the active ingredients of synthetic pesticides have been found to be carcinogenic thus posing a threat to human life. Biopesticides offer better alternative to synthetic pesticides due to their low toxicity, biodegradability and low persistence in the environment. The base materials for biopesticides are readily available and inexpensive. Data on toxicity levels, chemistry, active compounds and their compatibility with other methods of pests and disease management is needed to aid in formulation and commercialization. Globally, researchers have conducted studies on effectiveness of natural plant protection products with significant results being from *in vitro* experiments. Isman and Grieneisen, 2014 observed a rapidly growing publications on botanical insecticides, but much of the data is limited in its' reproducibility and thereby does not provide a basis for comparison with existing or future studies. Unfortunately, the studies do little to advance knowledge, except to add another species to the list of potentially useful plants. Lengai and Muthomi (2018) reported that there are studies on effectiveness of biopesticides under controlled environments and field conditions with varying results. Further research is therefore recommended to close the gaps in formulation of biopesticides. Stable products under field conditions will be a guarantee of utter effectiveness of biopesticides in crop pest management. Scientists and researchers should make greater efforts to investigate the utility of plant extracts for crop protection in field trials, in collaboration with local farmers, engineers in the government and industry because such studies should prove more valuable than laboratory-only studies, as well as providing stable, durable formulations of biopesticides.

Future Prospects

Kumar (2013) suggested that recombinant DNA technology being deployed for enhancing efficacy of biopesticides should continue, in addition to the continuous search for new biomolecules and improving of efficiency of known biopesticides. Also, fusion protein is being designed to develop next-generation biopesticides. This technology allows selected toxins (not toxic to higher animals) to be combined with a carrier protein which makes them toxic to insect pests when consumed orally, while they were effective only when injected into a prey organism by a predator (Fitches *et al.*, 2004). Several other innovative approaches are being applied to develop biopesticides as effective, efficient and acceptable pest control measure among the farmers and common man. Many biopesticides target a single pest species, but it is always desirable to have biopesticide that can control a range of pest species. Biological pesticides are expected to provide predictable performance, and they must do so in an economically viable manner for their better acceptability and adaptability.

Damalas, and Koutroubas (2018) recommended the co-operation between the public and private sectors to facilitate the development, manufacturing, and sale of this environmentally friendly alternative, as the discovery of new substances and research on formulation and delivery would boost commercialization and use of biopesticides. While new substances could serve as a promising option for use in pest control, more field research is required to assess the efficacy on specific pest problems in various cropping systems. Furthermore, microencapsulation based on nanotechnology could improve the residual action of biopesticides, and this could increase their field use.

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CHAPTER 2

Indigenous Traditional Knowledge: Application, Documentation, Advantages and Deficiencies

by

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Abstract

"The acquisition and practice of beliefs, laws, passed down generational lines, and modified through experiences, observations, and information made indigenous traditional knowledge (ITK) important. ITK as it is popularly referred to has allowed continuity and survival of indigenous families and traditional societies providing means of beating the odd in farming, dealing with environmental challenges, maintaining diverse life around the local communities, and in economic life of the people. While ITK is local and peculiar to poor people living in a particular place in their day to day living, it is adopted in other places to make survival possible. It is presently confronted with myriad of challenges such as loss resulting from youth migration to urban centers, introduction of new technology, disrespect from people who are not the originators, and unacceptance because of it unscientific nature. It is believed that documentation will help place ITK in the right position and place it should be, and its adoption along with scientific knowledge will go a long way in helping to provide solutions to a host of challenges that modern man presently faces, as the local knowledge is rich covering every area of human endeavor.

Keywords: Indigenous knowledge, Sustainable development, Communities, Generations, Documentation

a) Introduction

Indigenous traditional knowledge (ITK) is acquired knowledge for a given people, society, or community from generation to generation. It is unique mostly to poor communities, and it is indigenous and local in nature originating naturally (Altieri, 1995). Mahapatro *et al.* (2017) defined ITK "as the assemblage of awareness and understanding of various facts which people have developed over a large span of time and continue to expand it". Accumulation of these understanding through practical experiences and observations help the indigent people to survive through time, as the accumulated knowledge affords them the skills for surviving in their local under-developed domains (Rajasekaran, 1993). The indigenous communities are characteristically poor and mostly share religious belief, kinship, songs, taboos and others. The unique nature of ITK is seen in its specificity to a particular community or society, repetitive though unfixed in attribute, community ownership guiding community decision making processes, and dynamic and reproducibility. ITK is attributed to poor communities of the world where the local indigenous knowledge shapes their understanding of agriculture, health care, wildlife and forestry management, biodervisity and preservation (**S**harma, 2015; Anaeto *et al.*, 2013; Asiabaka, 2010; Warren, 1991). Pandey *et al.* (2017) opined that a flow of locally acquired knowledge is necessary for preservation, development, and sustainability of indigenous wisdom.

ITK has been variously described by terms like focal ecology, indigenous technical knowledge ethnology, indigenous knowledge, rural knowledge customary laws and knowledge of the land (Kyasiimire, 2010; Altieri, 1995). It shapes conservation and other day-to-day communal activities of the poor population. ITK is important because it helps in transmitting knowledge needed to sustain agricultural and the economic facet of life of the local society (Fernandez, 1994). The way of life of the indigenous people in managing their daily living is basically dependent on their belief, traditions, experiences, and acquired knowledge overtime. These understanding defines how they practice agriculture, conserve natural resources, practice traditional healing, and manage natural disasters issues so as to be able to survive. UNEP (2009) describes ITK as being local and indigent to a particular community, comprising accumulated knowledge resulting from acquired skills, belief and societal practices passed from generation to generation, transmission of which sharpens and fine-tunes it as a requirement for surviving and achieving a stable livelihood.

ITK originated from farmers, community leaders, elders, folklores, songs, myths, poetry, stories, languages, beliefs amongst others (Satapathy *et al.*, 2002). World Conservation Strategy of International Union in 1980 recognized the position of ITK, followed by the World Commission on Environment in 1987 and the United Nations conference on Environment and Education in 1992. The three bodies accorded ITK a position of recognition, as it afforded the traditional societies a united front as regards the management of the resources around them for survival. The bodies and others variously appreciated the contributions of ITK in societies and localities around the world. The indigenous knowledge is influenced by belief system, spirituality, brotherhood, experiences, wisdom of the people and their leaders which ultimately is dependent on the resources available to the community, so as to achieve and ensure quality minimal livelihoods for the survival and continuation of the local people. Passage of the knowledge from one generation to another refines and fine-tunes it to the extent that it becomes a code, a direction that guide their way of life (Pushpangadan *et al.*, 2002). Transmission of the knowledge is encouraged by its