ACTA UNIVERSITATIS SAPIENTIAE
AGRICULTURE AND ENVIRONMENT, **9** (2017) 95–106

DOI: 10.1515/ausae-2017-0009

Current status, challenges, and prospects of biopesticide utilization in Nigeria

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Manuscript received March 15, 2009; revised April 15, 2009

Abstract. The toxicity, persistence, and non-biodegradability of chemical pesticides have increased calls for the adoption of sustainable and cost-effective pest control measures. Biopesticides present a sustainable alternative to synthetic pesticides. However, the biopesticide utilization in agrarian countries like Nigeria remains low, resulting in increased chemical pesticide utilization. Therefore, this paper seeks to examine the current status, challenges, and prospects of biopesticides in Nigeria. The findings revealed that biopesticide utilization in Nigeria is low due to high costs, poor infrastructure, skilled manpower alongside inconsistent field performance and government policies. The solution to these challenges will significantly boost crop protection, food security, and sustainable agriculture in Nigeria.

Keywords: pesticides, food security, pest control, crop disease, Nigeria

1. Introduction

The United Nations estimates the global population will exceed 10 billion by the year 2100 [1]. Currently, the population of Nigeria estimated at 140 million accounts for one-quarter of the population of sub-Sahara Africa or one in every 6 black persons in the world [2, 3]. However, these statistics are set to soar in the

future, resulting in socioeconomic and environmental challenges for future generations [4]. As a result, analysts predict that energy, poverty, and food crises will become recurrent issues in the future [5, 6]. In view of the troubling state of things, countries with rising demographics urgently require sustainable strategies to address these issues, particularly the need to meet food requirements of growing demographics [7]. Currently, the dilemma facing human civilization is the capacity to enhance sustainable food production and address shortages and wastage [7, 8]. It is estimated that approximately 40% of the yearly crop production is destroyed by pests worldwide prior to harvest [9–11]. Likewise, nearly 20–30% of crops in Nigeria are damaged during post-harvest [12, 13]. Therefore, there is an urgent need for advanced food production, pest eradication, and disease management prior to harvest and post-harvest through the adoption of innovative, cost-effective agricultural practices. These efforts will ensure increased crop production and sustainable agriculture.

Over the years, conventional synthetic insecticides have been successfully utilized to control pests and boost crop production. Researchers around the globe have attributed the increased, albeit insensitive use of pesticides in the large-scale manufacturing processes to the increasing need for global food productivity [14]. However, recently, pertinent issues related to human health, safety, and the environment are threatening the continued use of synthetic pesticides [15]. Consequently, numerous researchers [16, 17] have reported the presence of different synthetic insecticides in various food products. In addition, the studies highlight the growing risks of agrochemicals to human health, the growing resistance to targeted pests and its unsustainable nature.

Hamilton and Ambrus [18] examined the effect of long-term and short-term (acute) dietary exposure to pesticide residues in food using a deterministic method or probabilistic methods. The results revealed that human exposure to, consumption or variability of pesticide residues in fruits and vegetables have considerably increased over the years [18]. As a result, the toxicity from short- and/or long-term exposure has become a growing concern among researchers.

Consequently, the study by Boobis et al. [19] examined the cumulative risk assessment of pesticide residues in food. The study highlighted various methods for assessing the cumulative toxicity of pesticides and the possible exposure scenarios using deterministic and probabilistic methods. In addition, the study revealed that exposure to pesticides can occur through food, water, residential or occupation pathways resulting in combined toxicological effects on humans and the environment [19].

Consequently, there is an urgent need to address the toxicological, socioeconomic, and environmental effects of increased pesticide utilization around the globe. This is critical to the sustainable food production and environmental protection, especially against the backdrop of appeals to mitigate the impending

effects of climate change and global warming in vulnerable developing nations of the world. Hence, the development and adoption of innovative practices, process, and products are urgently required. This can be addressed by using eco-friendly, bio-based pesticides (known as biopesticides) as substitutes for synthetic insecticides for crop production, pest and disease management.

Biopesticide is a generic term for pest control measures that utilize bioactive microbes derived from plant and animal sources for sustainable crop protection [20, 21]. More importantly, biopesticides are biodegradable alternatives to the synthetic insecticides currently utilized for pre- and post-harvest control of crop pests and diseases. Their use has gained traction over the years due to technological advancements in pest control and management. In addition, the growing acceptability of biopesticides has been prompted by the search for eco-friendly, benign and Integrated Crop Management (ICM) strategies for pest control and management [20, 22]. According to Mazid and Kalita [15], biopesticide utilization is a sustainable agriculture technique with minimal, often harmless residues in harvested food crops and the environment [15]. As a result, there has been growth in global market penetration, although biopesticides still account for a small fraction of pest control products [21].

Despite global acceptance and utilization, biopesticide penetration remains low, particularly in developing agrarian countries like Nigeria. This is mostly due to widely reported issues such as the high cost, poor efficacy, and inconsistent field performance associated with biopesticide utilization [21]. In addition, lack of knowledge, cohesive advocacy, and other factors have conspired to limit biopesticide use in Nigeria – and Africa in general. Therefore, this paper seeks to review the current status, challenges, and prospects of biopesticide utilization in Nigeria. It is envisaged that the findings will avail the academia, industry, and other agricultural stakeholders with requisite knowledge on current developments in biopesticides in Nigeria. The long-term goal is to foster sustainable crop production and environmentally sustainable agriculture in Nigeria through pest control and disease management.

2. Overview of biopesticides – types and mode of action

In general, biopesticides are considered environmentally friendly alternatives to chemical pesticides derived from microorganisms, natural sources or processes [21, 23]. This unique class of bio-based pesticides is produced by genetic incorporation of DNA into agricultural commodities to prevent damage from pests or diseases [22, 23]. In principle, biopesticides can be classified into three categories [23, 24], namely: Microbial pesticides (MCP), Biochemical pesticides (BCP), and Plant-Incorporated-Protectants (PIPs).

Microbial pesticides (MCP). This class of biopesticides typically comprises one of many microorganisms, such as bacteria, fungi, viruses, protozoans, or algae, genetically adapted for crop pest control. For example, the proteins produced by the bacteria *Bacillus thuringiensis* (Bt) is reportedly used for pest control in vegetables and root crops [23]. This class of biopesticides makes up the largest percentage of the market today. Therefore, MCPs are designed to control a different class of pests, though each active element is meant for a specific target. This occurs by restraining pests either through the production of disease causing endotoxins or by hindering the reproduction of other microorganisms through antagonism [25].

Biochemical pesticides (BCP). This class of biopesticides is derived from naturally occurring living materials such as plant extracts or sex pheromones that attract pests to traps [15]. BCPs typically operate by interfering with the growth or reproduction of pests, thereby preventing damage to crops. In principle, BCPs are composed of mainly plant extracts such as: antifeedants, pheromones, fatty acids, potassium bicarbonate, and plant growth regulators. In contrast to conventional synthetic chemical pesticides that kill or inactivate pests, biochemical pesticides merely impede the growth or reproduction of the pests through plant growth regulators or pheromones. Examples of plants or plant products used as biopesticides include: limonene and linalool, neem (*Azadirachta indica*), pyrethrum, pyrethrins, rotenone, and sabadilla – typically used to deter pests such as fleas, caterpillars, ants, aphids, and ticks [15].

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) [26]. 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 [26, 27]. Consequently, significant research and scientific resources are dedicated to PIPs as natural pest control agents.

In practice, PIPs are transgenetically engineered into crops using recombinant DNA technology to control pests [28]. These comprise substances excreted by organisms to alter the actions of a body of a similar or a dissimilar species. These plant- or animal-based secretions can operate by inducing behavioural retort in organisms of the same or different species. As a result, semiochemicals are categorized into two basic groups, namely; allele-chemicals and pheromones. Allele-chemicals are chemicals created by one species which cause a reaction in the body of another species. On the other hand, pheromones are substances secreted by organisms to influence changes in the body of similar species. During pest management, pheromones are used as lethal pesticides to attract and trap

insects, thereby interrupting mating. The deliberate disruption of pest reproduction is achieved by releasing proportionately large quantities of sex pheromones to confuse male pests. This ultimately reduces their ability to effectively locate females to mate. As a result, pheromones account for a sizeable percentage of the biochemical pesticides on the market.

Advantages and disadvantages of biopesticides. The use of biopesticides have numerous advantages such as low toxicity compared to conventional pesticides. In addition, biopesticides are biodegradable and decompose quickly upon application, minimizing exposure to humans, food, and the environment. This prevents bioaccumulation and, by extension, environmental pollution problems associated with synthetic pesticides. Biopesticides are also reportedly specific in action and operate by targeting only pests and closely related organisms which are a problem associated with chemical pesticides. As a result, biopesticides are environmentally benign and eco-friendly alternatives to chemical pesticides that can be effectively used for pest control and disease prevention.

In spite of its advantages, biopesticides reportedly have a short shelf life and field persistence, which may require a repeated application for the effective eradication of pests. As a result, this increases the cost of using biopesticides as a crop protection strategy. Furthermore, the specificity of biopesticides typically narrows down the target range of operation, which may require the use of many different types during intercropped or mixed cropping agriculture [29].

3. Biopesticides in Nigeria: historical overview

The synthetic chemical pesticide, lindane, was first introduced in Nigeria in the early 1950s. The influx of chemical-based pesticides was due to the need to boost agricultural productivity and crop yield due to rising urbanization and population. Therefore, pesticide use soared geometrically in 1960 after the country's accession to independence [13, 30]. Over the years, the adverse effects resulting from excessive utilization of synthetic chemicals have become widely reported [31]. Numerous studies have highlighted the toxic and persistent effects of pesticide residues on crop and food contamination along with soil and groundwater pollution [16, 27, 30]. In view of the above, there have been increased calls to discontinue the use of synthetic chemical pesticides in agriculture. Hence, the use of biopesticides is now advocated particularly in developing countries like Nigeria.

3.1 The current status of biopesticides utilization in Nigeria

The current status of biopesticide utilization in Nigeria remains low despite its widely reported benefits for crop protection and disease management in agriculture

[32–34]. The study by Okwute [33] identified, examined, and highlighted the potential of several plant-based sources of pesticide in Nigeria. The authors demonstrated that the leaf, bark, seed, root, and fruits of over 30 plant species in Nigeria contain bioactive pesticide agents. The author identified the following plants as potential sources of bioactive agents for pesticides: *Azadirachta indica, Cannabis sativa, Eucalyptus globules, Gmelina arborea, Balanites aegyptiaca, Khaya senegalensis, Nicotiana tabacum,* and *Prosopis Africana* [33]. Likewise, the study by Ekefan and Eche [34] identified numerous indigenous biopesticides for use in pest management in Nigeria. *Table 1* presents selected botanical insecticides used to control field pests.

Table 1. Botanical insecticides and field pests controlled in crops [33]

SN	Plant name	Product/ trade name	Group/mode of action	Targets
1	*Lonchocarpus* spp. Derris elliptical	Rotenone	Insecticidal	Aphids, bean leaf beetle, cucumber beetles, leafhopper, red spider mite
2	*Chrysanthemum cinerariaefolium*	Pyrethrum/ Pyrethrins	Insecticidal	Crawling and flying insects such as cockroaches, ants, mosquitoes, termites
3	*Nicotiana tabaccum*	Nicotine	Insecticidal, antifungal	Aphids, mites, bugs, fungus, gnat, leafhoppers
4	*Azadirachta indica*	Azadirachtin/ neem oil, neem products, Bionimbecidine	Repellent, Antifeedant, Nematocide, Anti-fungal	Nematodes, sucking and chewing insects (caterpillars, aphids maize weevils)
5	Citrus trees	d-Limonene Linalool	Contact poison	Fleas, aphids, mites, paper wasp, house cricket
6	*Shoenocaulon officinale*	Sabadilla dust	Insecticidal	Bugs, blister beetles flies, caterpillars, potato leafhopper
7	*Ryania speciosa*	Ryania	Insecticidal	Caterpillars, beetles, bugs, aphids
8	*Adenium obesum (Heliotis sp)*	Chacals Baobab (Senegal)	Insecticidal	Cotton pests

Likewise, *Table 2* presents some selected indigenous botanical insecticides used for pest control.

Table 2. Indigenous botanical insecticides for pest control [34]

SN	Botanical insecticide	Pest controlled
1.	2% Hot pepper fruit extract	Foliar beetles, *Ootheca* sp., *Maruca vitrata*, *Heliothis armigera*
2.	"Fagara" root bark water extract	Cowpea flower thrips (*Megalurothrips sjostedti*), Pod borer (*Maruca vitrata*) and pod bug complex
3.	Neem leaf water extract	Okra leaf beetle (*Podagrica* spp)
4.	Chilli pepper	Aphids and other pests in vegetables
5.	Aqueous neem seed extract	Tomato fruit worm (*Heliothis armigera*), white fly, aphids
6.	Neem leaf	Nematodes in yam mini set termites and nematodes
7.	Neem seed cake	Stem borers in eggplant, nematodes in tomato
8.	Aqueous tobacco extract	Aphids, flea beetles, white flies, stem borers, caterpillars and mites

The study noted that natural pesticides can be extracted from fresh dried products, liquid secretions, powders, or cakes of indigenous plant species in Nigeria. In addition, the study highlighted that the low toxicity, eco-friendliness, and acceptability may account for the infancy of biopesticide utilization in Nigeria. This view is corroborated by Oruonye and Okrikata [32] and Okwute [33]. *Section 3.2* will highlight the challenges facing biopesticide utilization in the Nigerian agricultural sector.

3.2 Challenges of biopesticides utilization in Nigeria

The general consensus is that biopesticide use in Nigeria is plagued by numerous challenges. Chiefly, the poor enforcement of the country's pesticide regulation is hampering the development, adoption, and diffusion of biopesticides. Notwithstanding, various authors note that different field studies on indigenous biopesticides are still ongoing with follow-up tests, field work, and laboratory trials. It is envisaged that the success of research in this field will explore the thousands of plant resources, which, according to Ekefan and Eche, [34] abound in Nigeria. In their opinion [34], the low usage and patronage of biopesticides are

hampered by numerous factors. In general, these factors can be broadly classified into political, technological, and socioeconomic.

Political. The political factors hindering biopesticide development, adoption and diffusion are centred on government policies in Nigeria. The role of the government is to stimulate, regulate, or supervise the development, distribution, and utilization of manufactured products in the country. The broad anthology of living and non-living entities present in biopesticides vary considerably in their properties, mode of action, fate, composition, and behaviour within their surroundings. As a result, the government needs to set strict health, safety, and environmental monitoring regulations before granting approval for the production and handling of biopesticides. To this effect, numerous government agencies, such as SON (Standards Organization of Nigeria) and NAFDAC (National Agency for Food and Drug Administration and Control), have been charged with ensuring public health and safety. However, Ekefan and Edge [34] note that the lack of governmental interest and clear policies on biopesticide development, regulation, and implementation in Nigeria has hampered progress. Furthermore, this has hampered investments in knowledge development, marketability, and accessibility to biopesticides in Nigeria. In addition, the lack of government support and advocacy for biopesticides has deterred farmers from patronizing biopesticides in Nigeria [32]. Hence, pest management technologies and strategies have been abysmally low.

Technological. The technological factors hindering biopesticide development in Nigeria are centred on the lack of solid research and development infrastructure in the country. The academia and industry lack the requisite scientific knowledge and technological skills to research, develop, and commercialize biopesticide products. This view that poor technological infrastructure is the faulty biopesticide application in Nigeria is corroborated by Lale [35]. The author further noted that the development and application of indigenous biopesticide products, such as oil and dust formulations, are poor. As a result, most biopesticide products on the Nigerian market today are not derived from standard clinical, laboratory trials or field data. This clear lack of research capacity presents significant risks to human health, safety, and environment. Furthermore, the lack of capacity severely hampers data-driven monitoring and assessment required to compare biopesticides with its synthetic derivatives. Hence, cutting edge scientific and industrial infrastructure is required to develop and test biopesticides in Nigeria. Furthermore, skilled personnel and modern equipment are required to monitor and assess the effects of biopesticides on human health, safety, and the environment. This will ensure that pertinent issues, such as toxicity, shelf life, and efficacy of bio-pesticides, are adequately addressed. This will reassure the generality of farmers who reside in rural areas to embrace the quest for sustainable agriculture.

Socioeconomic. The socioeconomic factors hampering biopesticide development and widespread utilization are centred on the cost and social acceptability. As earlier stated, low government promotion and patronage has severely impacted on the availability and acceptability of biopesticides in Nigeria. More importantly, the cost of producing and procuring biopesticide products remains high due to the lack of industrial production. Hence, biopesticides cannot favourably compete with their synthetic derivatives in terms of cost, resulting in low market penetration and availability. It stands to reason that the high costs will deter farmers, thereby hampering acceptability of such products in spite of their benefits. In the long term, this reinforces the first-mover advantage enjoyed by synthetic pesticides in pest management industry. However, the lack of technological leadership of biopesticides presents numerous opportunities for sustainable agriculture in Nigeria. Section 3.3 will briefly present the opportunities for biopesticide development in Nigeria.

3.3 Prospects of biopesticides utilization in Nigeria

As outlined, biopesticide development in developing countries is hampered by numerous challenges such as lack of awareness, confidence, and acceptability. Other factors include lack of data-driven standards and monitoring of field performance, which hampers marketability, product quality, and shelf life. Furthermore, lack of regulatory framework, health, and ecological risk assessment have all conspired to disadvantage biopesticides in comparison with chemical pesticides. However, these challenges also present numerous opportunities for biopesticide development in Nigeria.

The *political* challenges can be addressed by renewed government support of agriculture in the country. The policy objectives of the Agriculture Promotion Policy (2016–2020) [36] aimed at pesticide minimization in agriculture need to be enforced stringently. In addition, the implementation of APP must focus on the importance of biopesticides on sustainable agriculture in Nigeria. Hence, the redirection of the APP policy vis-à-vis government participation will spur the development, utilization, and acceptance of biopesticides in the Nigerian agriculture. This will increase private-sector participation, financial investments, and long-term growth – factors which are required to promote this valuable sector of the Nigerian economy.

Numerous *technological* opportunities can be derived from biopesticide development in Nigeria. The involvement of the government and industry will stimulate academic research and technological development in this sector. Over the years, R&D in Nigeria, particularly in the nation's tertiary and research institutes, has experienced numerous challenges. The palpable lack of research funds (grants), modern equipment, and other bureaucratic bottlenecks have conspired to stifle

R&D efforts aimed at developing and commercializing home-grown technologies. The clear lack of synergy between the academia and industry has stemmed growth as well as the availability, acceptability, and abundance of biopesticide products in the Nigerian market.

The *socioeconomic* opportunities potentially accruable from implementing biopesticides in Nigeria are significant. Firstly, this will increase crop productivity and food security alongside health and safety in the country. It is estimated that about 40% of all harvested crops in Nigeria are lost due to pest damage [37]. Hence, the effective development and implementation of biopesticide initiatives will address the perennial problems of crop losses (wastage) and improve the profitability and sustainability of food production in Nigeria. In addition, the sector will – directly and indirectly – create jobs and improve the living standards of farmers – mostly composed of poor rural dwellers – in Nigeria. Lastly, biopesticides can improve the overall lifecycle of agriculture in Nigeria from pre-harvest to post-production required to ensure food security and sustainability in Nigeria.

4. Conclusions

The paper examined the current status, prospects, and challenges of biopesticide utilization in Nigeria. The aim was to identify and highlight knowledge required by government, industry, and other agricultural stakeholders to make informed decisions on the future of sustainable agriculture in Nigeria. The findings revealed that biopesticide development, acceptability, availability, and utilization are low in Nigeria. This is generally ascribed to numerous political, technological, and socioeconomic factors. However, the clear lack of government policy on biopesticides in Nigeria leaves a lot to be desired. Consequently, there is lack of motivation for investors to fund the technological infrastructure, R&D, and skilled manpower required for the economic growth and sustainable development of the sector in Nigeria. In view of this, the availability, marketability, and acceptability of biopesticides remain low. Hence, all stakeholders must work cohesively to stimulate growth and development in the sector. This will significantly boost sustainable crop production, food security, and environmental sustainability in Nigeria.

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