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Bio-Insecticides: The One- Health Response to Mosquito-Borne Diseases of Public Health Importance

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Abstract
Mosquito-borne diseases are among the leading causes of human and animal illnesses and deaths globally. Mosquitoes are found throughout the world; are nuisances, hosts and vectors of many disease-causing parasites of public health importance. These diseases include malaria, dengue fever, yellow fever, etc. Mosquitoes pose significant threat to human and animal health, are a global challenge with huge medical and economic impact. Control of mosquitoes is a major component of vector-disease management; chemical insecticides remain the mainstay of control as documented in scholarly reports. The effectiveness of available methods have been limited by factors including insecticide resistance, high operational costs, toxicity on non- target organisms and environmental pollution. The emphasis on public health and environmental protection has led to global concerns about these risks and prompted the search for environmentally-friendly products. Bio-insecticides are based on natural products or microorganisms and are able to control pests including insect vectors effectively with minimal environmental impact. This paper comments on the significant research progress for bio-developed insecticides in response to the need for eco-friendly products, the role of multidisciplinary approach to encourage innovation in bio-insecticide development and its application as a one-health response to mosquito-borne infectious diseases of Public Health importance.

INTRODUCTION

BIO-INSECTICIDES

The selective pressure of conventional synthetic insecticides has enhanced the resistance of mosquito populations at an alarming rate, resulting in wide spread resurgence, undesirable effects on non-target organisms and environmental and human health concerns: thus increasing the demand for new products that are environmentally safe, target specific and easily degradable.

Bio-insecticides are based on natural products like naturally occurring chemicals such as plant extracts and pheromones or microorganisms like bacteria, they are used to target various mosquito vector species and have been long touted as alternatives to synthetic chemical insecticides for vector and pest management because they pose little threat to human and environmental health [1]. The emphases in this review are the plant based products; several plants have been identified with insecticidal and pesticidal properties either in the seeds, fruits, barks, roots or in their root exudes while numerous plant products have also been reported either as insecticides for killing larvae or adult mosquitoes or as repellents for mosquito biting and are one of the best alternatives for mosquito control [2, 3].

CHARACTERISTICS AND ADVANTAGES OF BIOINSECTICIDES

Bio-insecticides including plant derived products have received much attention due to their natural chemical defences against insect pests and they now provide an effective alternative method to broad spectrum synthetic insecticides because they effectively reduce dependence on synthetic insecticides. Bio-insecticides are usually target specific in action, most of them must be ingested by the insect vectors or pests, they are primarily harmful to these vectors and pests, do little harm to beneficial insects, hence, they are less prone to insect resistance and resurgence due to their subtle and target specific mechanisms of attacking insects. They are biodegradable, thus reducing the ability to bio-accumulate in the environment. In terms of cost, these plant based bio-insecticides are readily accessible, are cheap, affordable and available. In addition, these products reduce environmental pollution and injustice while they enhance maximum protection and safety among producers and users as most are rapid acting and are of low to moderate toxicity to mammals. Overall, the mode of action of these insecticides gives it a comparative advantage over synthetic insecticides that are usually broad spectrum in action. Also, ability of these bio-insecticides to cause mortality to arthropods at relatively low concentrations also reflects their viability as alternatives to the use of synthetic insecticides in the control of disease vectors [4, 5].

LIMITATIONS

One limitation of these products is their rapid breakdown ability, while this makes it less risky to health and the environment it often creates a need for precise timing or more frequent applications [6]. Also although often thought as natural and hence assumed harmless, safety clothing must be worn when spraying these, even though

their toxicity is low to warm blooded animals, some bio-insecticides have been found to be toxic to fish and other cold blooded creatures and should be handled with care [7,8,9,10]; some have also been found to be lethal to a wide range of insects including natural predators and parasitoids, an example is the active ingredient of derris dust found to be lethal to a wide range of insect species as well as earthworms and fish, therefore it is advisable not to use the product near dams and waterways [8].

EFFICACY OF BIO-INSECTICIDES

A survey of literature on control of different species of mosquito reveal that assessment of the efficacy of different bio- insecticides have been carried out by a number of researchers in recent years and several of them have been considered as potential natural alternatives to conventional insecticides in the field of vector control. Bio-insecticides act primarily as toxins, larvicides, repellents, Growth inhibitors, anti-feedants and anti-ovipositors, to a wide range of insect vectors and the degree of toxicity of different products differ considerably from species to species [11, 12, 13].

LARVICIDES

Extracts of *Cinnamomium* species have been reported as effective mosquito larvicides [14, 15], Okumu et.al [12] reported that neem oil formulation was toxic to third instar larvae of *An. Gambiae* while the effectiveness of the extracts of *Piper nigrum* Linn., against *Culex pipiens, Aedes aegypti* and *Aedes togoi* have been established to cause behavioral changes and larval mortality [16]. Leaf extract of *Lantana camara* and *Catharanthus roseus* were found to be highly toxic to *Aedes aegypti* even at very low doses [17]. Ajayi [18] found that methanol extract of *Moringa oleifera* root gave 100% mortality within 24 hours exposure of Anopheline larvae to the treatment. And the evaluation of the activity of *Pinus longifolia* (Pine) oil against mosquito showed that it had larvicidal activity against various species of mosquitoes [19] while aqueous extract of *Solanum villosum* (berry) were found to be highly larvicidal on the dengue vector, *Stegomyi aaegypti*.[20]. Prabhu *et. al*., [21] reported that the seed extract of *Moringa oleifera* exhibited larvicidal activities on different instars of the malarial vector, *Anopheles stephensi*. Early reports on the use of plant extracts against mosquito larvae shows that chemicals from plant extracts have larvicidal effects on mosquitoes among other effects. Campbell *et.al*. [22] reported that extract from the Russian weed, *Anabasis aphylla* was larvicidal to *Culexsp* larvae. Ajayi [18] screened 48 medicinal plants in Nigeria for their antimicrobial activity and 23 of these plants (47.91%) caused over 70% mortality of the test organism including Anopheline and Culicine larvae. Nath *et. al*., [23] indicated that root extract of *Moringa oleifera* showed larvicidal activity against *Aedes albopictus* and *Culex quinquefasciatus* at higher doses. Studies with Water extract of *Moringa oleifera* seeds showed 24-hour-LC_{50} value of 1260 ug/ml against 3rd instar larvae of *Aedes aegypti* [13].

Larvicidal activity may vary depending on the mosquito species and geographical location where plant was sourced as these will determine the level of susceptibility of the mosquito species to the extract and also the weight of soluble solids content present in the plant extract respectively.

REPELLENTS

Thousand of plants have been tested and a whole lot of researches are still ongoing to identify potential sources of insect repellents, however only a few plant derived repellents demonstrate broad effectiveness and duration. Plants whose extracts have been found to have repellency activity include neem, citronella, pine, cedar, basil, Lemon grass, peppermint, lavender. Most of these provide short term protection usually about 2-3 hours [24, 25, 26, 27]. Susceptible mosquito species include *Culex, Aedes aegypti, Anopheles gambiae* and these have been screened under laboratory conditions using human subjects and or laboratory animals [28, 29, 30]. Ansari *et.al.* [19] reported that *Pinus longifolia* (Pine) oil had repellent activity against various species of mosquito. Bio-isecticides may play an important part in mosquito and arthropod-borne disease control through the lure and kill technique.

PROLONGATION OF DEVELOPMENTAL PERIOD

The benefits of larval prolongation is that mosquito larvae numbers are reduced due to the longer periods needed for new generations to complete the mosquito life cycle [31] Many studies have drawn attention to the effects of plant extracts on growth retardation and elongation of developmental periods on mosquito species. Okumu *et. al.*, [12] found that exposure of *Anopheles gambiae* larvae to *Azadirachta indica* oil formulation resulted in prolonged larval periods, significant reductions in growth indices and pupation. A methanol-aqueous extract of *Nerium indicum* leaf at 100mg/L was reported to have elongation effect on the pre-imagio period for all the larval instars of *Aedes aegypti* treated compared to the control [32]. Ohia [33] reported delay in larval development of *Anopheles gambiae s.s* to the pupal stage after exposure to aqueous extract of *Moringa oleifera* especially at lower concentrations. Promisiri *et. al*., [11] posited that there was delay in the development of *Aedes aegypti* larvae to the pupal stage after exposure to three medicinal plants, *Mammea siamensis, Anethum*

graveolens and Annona muricata. Prabhu *et. al*., [21] reported the pupicidal potential of the seed extract of *Moringa oleifera* against the malarial vector *Anopheles stephensi.* However Ferreira *et. al.,* [13] found that water extract of *Moringa oleifera* seeds did not demonstrate capacity to prevent egg hatching on *Aedes aegypti.* The effect on prolongation of developmental period reported in these studies may be due to chemical compounds in the plant extract preventing normal pupation and preventing movement to the next developmental stage thus preventing adult emergence from occurring with the resultant effect of reducing the mosquito population.

BIO-INSECTICIDE DEVELOPMENT FRAMEWORK

In recent years, several bio-insecticides have been considered as potential natural alternatives to conventional insecticides in the field of vector control. A development framework therefore is important to guide the research and development of these products and enhance transition from the laboratory to the field where there is increased need for prompt action against mosquitoes and mosquito-borne diseases. In the light of this, we suggest a development framework to serve as guide in the development of bio-insecticides (Fig. 1).

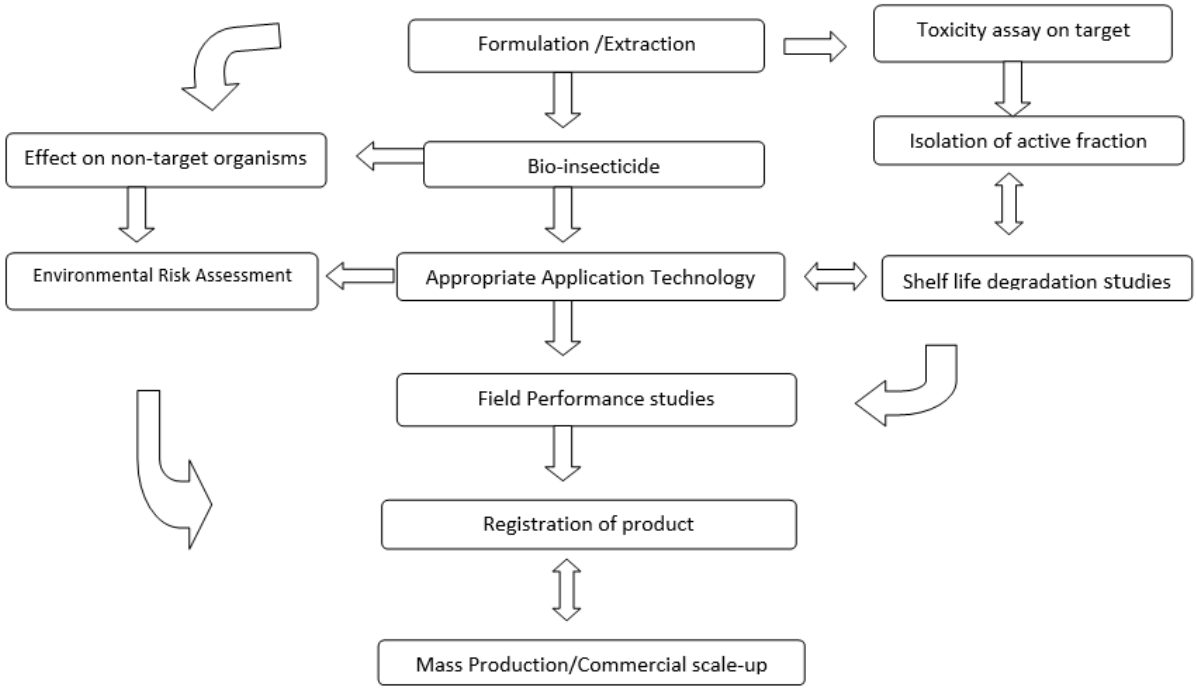

Figure 1: Bio-insecticide development framework. (Courtesy author)

CONCLUSION

Role of multidisciplinary approach in encouraging innovation in bio-insecticide development

The need for more environmentally- friendly forms of insecticides is greater now than ever and biotechnologists and entomologists agree that mosquito control efficiency should be with selectivity for a specific target organism, this is one of the high point of bio-insecticide development because of the specificity on the target organism. More so, is the fact that the development should involve an inter-sectoral and inter-disciplinary approach cutting across disciplines like Entomology, Chemistry, Veterinary Medicine, Agriculture, Public Health, Politics, Information and so many others.

The diversity of plant species is huge and phytochemicals obtained from them are important sources of safe and biodegradable chemicals which can be screened for mosquito and insecticidal activities and tested for mammalian toxicity [34]; A better understanding of the mode of action and effects of bio-insecticides and of the regulatory issues that arise in their adoption may help to raise their profile among stakeholders especially policy makers and thus enable the realization of their potential contribution to sustainable vector control globally.

Bio-insectides can effectively control mosquito vectors of Public Health importance when used as part of an intergrated vector control programme. However their regulation is more or less non-existent and where available these regulations are governed by a system originally designed for chemical insecticides and this acts as a barrier to investment in bio-insecticide research and development. In the light of this, it is of paramount importance that stakeholders arise to this opportunity to invest and divest all available resources to the development of bio-insecticides to adequately enhance the global fight against mosquito-borne diseases.

We opine that bio-insecticides can be used in much similar ways as conventional insecticides; as they present new potential modes of action, are effective in controlling the insect vectors at various stages through

larvicidal, ovicidal, repellency and Insect Growth Regulatory mechanisms and advocate a one-health, multidisciplinary approach, more concerted research to quantify the contribution of products' active ingredients and determine their vulnerability to genetic variations in insect populations that lead to insecticide-resistance, to make them more appealing to policy-makers and vector control programmes. This requires commitment of various stakeholders, institutions and agencies involved in the fight to combat mosquito-borne diseases globally through support and injection of funds for more research, adequate monitoring and evaluation to provide predictable performance standards through cost- effective methods to enhance bio-insecticide registrations and commercialization.

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