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STATUS AND PROSPECTS OF BIOLOGICAL CONTROL OF MOSQUITOES IN NIGERIA

ANTHONY OKECHUKWU EJIOFOR
Department of Applied Microbiology and Brewing,
Anambra State University of Technology, P.M.B. 5025, Awka, Nigeria

ABSTRACT

Nigeria is covered, in the south, by the tropical rain forest and, in the north, by the Savannah. The entire country is thoroughly watered, in the coastline, by the Atlantic Ocean and, in the hinterland, by numerous rivers, lakes, streams and ponds. The water situation is further increased by numerous open drains and gutters in urban centres as well as the massive irrigation projects which are fallouts from Nigeria's agricultural revolution. The consequence of this is that most of Nigeria constitutes a favourable breeding ground for various species of mosquitoes. The density of population could be as low as 1 or as high as over 20 larvae per dip depending on the site and the season. The most important mosquitoes in Nigeria, frompublic health point of view, a*re Aedes aegypti, Culex pipiens quinquifas- ciatus, Anopheles funeslus* and subspecies of the *An. gambiae* complex. Although no large-scale mosquito control programme has ever been organized in Nigeria using chemical insecticides, reports of group resistance to organochlorines, organophosphates and carbamates have been available since 1956. Biological control agents therefore have a chance for a good start in Nigeria. So far, biological control efforts are supported entirely by the WHO. Among the biological control agents already experimented upon *are Bacillus thuringiensis* serotype H-14 and B. *sphaericus* strains 1593 and 2362. Local materials like cowpeas *(Vigna unguiculata),* maize (*Zea mays),* bambara beans, cattle blood and cassava juice have been used to compound fermentation media. pH are controlled with lime juice *(Citrus aurantifolia)* and extracts from burnt defruited palm regime. Production have,however, not gone beyond bench top fermentors. Tests are carried out either with large volumes of final whole cultures or powders obtained by lactic acid-acetone coprecipitation technique. Field trials have been conducted in rice fields, open drains, ponds, roadside ditches, water cistems and artificial plots with excellent results against all mosquito species present. Research on the production of stable local formulations is currently going on.

INTRODUCTION

The geographical features of Nigeria and indeed those of many tropical African countries provide excellent environmental conditions for the breeding of many species of mosquitoes (Culicidae). Ecological and taxonomic information on mosquitoes in Nigeria is fairly well known. Mosquito-bome diseases of man abound in the tropics and this explains the endemicity of such diseases as malaria and filariasis and the sporadic epidemicity of yellow fever.

The Federal and State Governments in Nigeria have shown considerable interest and concern about the control of these diseases as manifested in the planning and execution of (albeit improperly co-ordinated) programmes such as the National Malaria Control Programme, the Rural Health Care Programme and the current Primary Health Care Programme. These programmes relied heavily on the use of chemical insecticides and chemotherapeutic preparations.

In spite of all these programmes the problems posed by mosquitoes and mosquito-borne diseases have remained virtually intractable. In fact, the situation has been worsened by the recent estab-

lishment of more than twenty River Basin Development Authorities throughout the Federation, mostly in the semi-arid north. The development of these authorities is part of the Federal Government's plan to make Nigeria self sufficient in food production. The authorities consequently developed irrigated farmlands and swamp rice culture has flourished. These irrigated farms have tremendously increased the hectarage of suitable breeding grounds for many species of mosquitoes.

However, only very little base-line data and research information are available for the development of an effective strategy for the control of mosquitoes and other medically important arthropod vectors in Nigeria. It was in the light of this that many workshops on the "Control of Pests and Disease Vectors in Nigeria" were held. The latest in the series was (February, 1988) at the University of Jos, Nigeria. The first workshop which was specific on the Biological Control of Insects in Nigeria was convened by the WHO in Kaduna in April, 1977. This WHO initiative can be said to be the beginning of serious attention on the control of insects of medical importance by microorganisms in Nigeria. Following this workshop, a "Biological Control Unit" was established at the University of Nigeria, Nsukka, under the direction of Professor Nduka Okafor and under the auspices of the WHO. This unit initiated collaborative research and training programmes with many Biological Control Centres in many parts of the world. Ever since, significant efforts are being made, there is steady increase in the number of skilled manpower, small scale field trials have been done, substrates for local production of biocides have been researched upon and work is progressing on suitable local formulations of proven bacterial mosquito larvicides.

The prospects of large-scale programmes for biological control of mosquitoes in Nigeria *per se* or as an integral part of a larger programme is very bright. The achievement of desired goals will invariably depend on very strong support from the governments of Nigeria as well as from interested international organisations. Of course there is still a very urgent need to develop various ecological zones of Nigeria, especially the mangrove swamp delta areas which have very difficult terrain.

ECOLOGY OF NIGERIAN MOSQUITOES

The successful control of mosquitoes is usually based on the understanding of the ecology and bionomics of the vector, including the distribution of these disease vectors in space and time. Their habitats, longevity, resting and feeding as well as breeding habitats and vectoral capacities are important factors. The exact knowledge of the ecology of mosquitoes enables intervention measures to be precisely applied without undue interference with non-target organisms and with minimum contamination of the environment. There is also the need to monitor the response of the mosquitoes to available chemical and biological insecticides.

There are gaps in the knowledge of the ecology and bionomics of vectors in Nigeria. These gaps are widening further owing to the identification of new species from complexes. For example, from the *Anopheles gambiae* complex six species have been identified of which three are found in Nigeria; *An. gambiae* sensu stricto, *An. arabiensis* and *An. melas* (Ekanem, 1979). These species are identified from cytotaxonomic criteria and not from morphological characters. The identification and mapping of the various mosquito species in Nigeria and a detailed study of their ecology and behavioural patterns require the urgent attention of experts in the field. It is also necessary to establish simpler methods of identification to facilitate ecological studies.

Meanwhile there is a great diversity in mosquito habitats covering all the ecological zones of Nigeria. *Anopheles* species generally prefer brackish water, ditches, rockpools, ponds, streams, tins, puddles and sand-pits (Service, 1963; Ogunba, 1979). *Culex* species breed abundantly in ditches, marsh pools, tree holes, tins, septic tanks, latrines and open drains while *Aedes* species are found in bamboo trees, coconut shells, containers, tins, broken pots, plant axils, tree holes and discarded tyres (Service 1965, 1976). *Mansonia* species are found in ditches and rivers with water plants (Table 1). A recent study of some rice fields revealed that two species of the *An. gambiae* complex, *An. funestus* (Ejiofor and Okafor, 1985), *Culex duttoni* and *Cx. pipiens quinquefasciatus* (Ejiofor, 1983) breed

TABLE 1
Breeding habitats of some mosquitoes of Nigeria

Species	Habitat
Ae. aegypti	Water cisterns, tins, broken pots, tree
Ae. africans	Bamboo trees, coconut shells
Ae. simpsoni	Plant axils
An. barberellus	Ditches, rockpools, ponds
An. coustani	Ditches, rockpools, ponds
An. funestus	Ditches, rockpools, ponds, rice fields
An. obscurus	Ditches, rockpools, ponds
An. paludis	Ditches, rockpools, ponds
An. gambiae	Ditches, puddles, sandpits, rice fields
An. hargreavesis	Ditches, rockpools, streams, tins
C. annulioris	Among filamentous algae in ditches
C. antennatus	Ditches, tree holes, tins, stagnant pools
C. univittatus	Ditches, tree holes, tins, stagnant pools
C. decens	Ditches, marshpools
C. invidiosus	Ditches, marshpools
C. guiarti	Ditches, marshpools
C. tigripes	Ditches, marshpools
C. duttoni	Ditches, marshpools, rice fields
C. nebulosus	Tree holes, tins
C. moucheti	Tree holes, tins
C. pipiens quinquefasciatus	Septic tanks, latrines open drains, fallow rice fields
Mansonia africana & M. aurites	Ditches and rivers with water plants

abundantly in these fields in succession. Other aspects of the ecology of mosquitoes in Nigeria, e.g. biting habits, resting places, flight range, abundance, etc., have been extensively dealt with by several authors in the past (Mattingly, 1951; Mellamby, 1956; Service, 1963 and Peterson and Lambretch, 1976a,b).

MOSQUITO-BORNE DISEASES OF NIGERIA

Many serious human diseases of man are transmitted by mosquitoes in Nigeria. Adult *Anopheles* mosquitoes are the most important vectors of malaria and Bancroftian filariasis. More than eighteen anopheline species are known malaria vectors in Nigeria but the most important ones are *An. gambiae*, *An. funestus* and *An. melas* (Ogunba, 1979). Malaria is a major disease of the tropics which has no respect for any social class. The overall infection rate however has bearing with socio-economic background and the environment of the Nigerian population. The economic loss of manpower is quite apparent. More than 60% of all the arthropod-borne diseases of man in Nigeria have been diagnosed as malaria (Okpala, 1979).

Culex pipiens quinquefasciatus (= *C. quinquefasciatus; C. fatigans*) is the most important culicine vector because of its importance both as a biting pest and as the vector of Bancroftian filariasis. Other important species include *C. nebulosus*, *C. decens*, *C. tigripes* and *C. cinereus* all of which are involved in biting nuisance and viral transmission.

The *Aedes* mosquitoes in Nigeria are mostly involved with the transmission of viruses. The most important aedes spp. is *Aedes aegypti*, the vector of yellow fever. Other important members include *Ae. simpsoni*, *Ae. africanus*, *Ae. vittatus* and *Ae. longipalpis*.

Mansonia mosquitoes transmit arboviruses and also constitute a big biting nuisance especially in environments with ponds containing heavy growth of water plants. It is doubtful if they do transmit parasites in nature although Ogunba (1972) showed that *M. africanus* could transmit loa loa in the laboratory. In many coastal areas of Nigeria, *M. africanus* perhaps constitutes the commonest species that attacks man for bloodmeals outdoors during the day. They also commonly invade the houses in the mornings and evenings with the peak of their activity at 0400 and 2200 hours respectively (Ogunba, 1974). A summary of the diseases transmitted by mosquitoes in Nigeria is presented in Table 2.

TABLE 2
Mosquito vectors of human diseases in Nigeria

Common name	Important species	Disease transmitted
Anopheles		
mosquitoes	*An. gambiae*	Malaria
mosquitoes	*An. funestus*	
	An. melas	
	An. gambiae	Filariasis
	An. funestus	(*W. bancroffi*)
Aedes		
mosquitoes	*Ae. aegypti*	Yellow fever
	Ae. africanus	
	Ae. simpsoni	Dengue and other viruses
	Ae. leucocephalus	
	Ae. irritans	
	Ae. vittalus	
	Ae. longipalpus	
Culex mosquitoes	*Cx. p. quinquefasciatus*	Viral encephalitis
	Cx. nebulosus	
	Cx. decens	
	Cx. duttoni	
	Cx. tigripes	
	Cx. cinereus	
Mansonia mosquitoes	*M. africana*	Yellow fever
	M. uniformis	Viral encephalitis

THE NEED FOR BIOLOGICAL CONTROL OF MOSQUITOES IN NIGERIA

Records of field chemical control of mosquitoes in Nigeria are relatively few. Among such records are those of Elliot (1955), Kuhlow (1960), Paul and Self (1968), and Rosen *et al.*, (1973) which dealt with field control trials against many species of mosquitoes among other arthropod vectors of disease. These records indicate that all the major groups of chemical insecticides viz, pyrethroids, organochlorines, organophosphorus and carbamates, have been used against anopheline and culicine mosquitoes since 1950. There have also been reports of the use of these chemical insecticides for the control of agricultural pests.

As a result of agricultural and public health uses of these insecticides in Nigeria, there have been reports of resistance to them by mosquitoes in Nigeria since 1956. In fact more than 50% of the known resistant species of *Anopheles* mosquitoes thrive freely in Nigeria (Brown and Pal, 1971).

The problem of environmental pollution by pesticides, with the real and potential risks of their

harmful effects on nontarget organisms exists in Nigeria. Koeman (1971) produced evidence of possible defaunating effects of dieldrin on insectivorous as well as herbivorous and carnivorous birds in North Eastern Nigeria in November 1969 during a tsetse (*Glossina*) control programme. Similar trends were also reported with respect to other pesticides and various categories of vertebrates affected by insecticide spray trials conducted in many cases for agricultural and other purposes.

Finally, the problem of cost, in terms of procurement rates of pesticides and the equipment needed for their application, is a very serious one in Nigeria. The global oil glut and the increased cost of refining petroleum have made chemical insecticides outrageously expensive and have, therefore, made large-scale chemical control programmes economically unwise.

It has therefore become necessary to look at the biological alternative/complement to the chemical insecticides. Efforts will be made to review the beginning of research in the biological control of mosquitoes, the present status and the future prospects.

BIOLOGICAL CONTROL OF MOSQUITOES IN NIGERIA

Before the advent of modern organised biological control of mosquitoes in Nigeria, there had been reports of the use of the non-bacterial agents, especially predators for the control of some mosquitoes. These agents include the predaceous *Toxorhynchites* and fish, *Gambusia affinis, Tilapia zilli; T. hendelloti, T. lebretoni* and *Poecilia reticulata* (Pal, 1980a).

Toxorhynchites is a genus containing 66 species of large non-biting mosquitoes, the larvae of which are predaceous on mosquito larvae inhabiting natural and artificial containers such as leaf axils, tree holes, water cisterns, discarded bottles, tyres and cans. The genus is circum-tropical and occurs as far as the 15th parallel in the northern hemisphere. Four species have been considered globally for biological control of mosquitoes. These are: *Tx. brevipalpis, Tx. splendens, Tx. amboinensis* and *Tx rutilus* (vars *rutilus* and *spetentrionalis*). Of these only *Tx. brevipalpis* var *contradti* (Pal, 1980b) was found in the South Eastern parts of Nigeria on the borders of Cameroon. Another species *Tx. erythrurus* was found in great abundance in the Ibadan area of Western Nigeria but its predatory capacity has not been fully established. Nevertheless, no large-scale "Tox" programme has been carried out in Nigeria.

The practice of control of mosquitoes by deliberate introduction of larvivorous fish into mosquito-breeding waters is old and stems from repeated observations in the field and in the laboratory, that certain small fish are voracious feeders on mosquito larvae and pupa. Two hundred and sixteen species from 30 families have been used against 35 mosquito species in 41 countries to control the yellow fever mosquitoes (*Ae. aegypti*) and the malaria mosquitoes (*Anopheles* spp.). In Nigeria the practice has been in use since 1948 when the local species *Tilapia hendelotti* and *T. lebretoni* were used for the control of *Anopheles* and *Culex* species in the Lake Chad area of North Eastern Nigeria (Pal, 1980a). On the whole, biological control by fish has not been widely practised in Nigeria because of the usual problem of space and difficulty in the transportation of bulky exotic fish.

There have been no reports of the use of microsporidia, mermithid worms, fungi or genetic control of mosquitoes on any scale in Nigeria although there are instances of isolation of *Parathelonia africana* and *Coelomomyces lacunosus lacunosus* from *An. gambiae* larvae from a rice field environment in Nigeria (Ejiofor, 1983).

The use of microbial pathogens of mosquitoes for the control of mosquitoes in Nigeria has been confined to bacterial pathogens notably *Bacillus thuringiensis israelensis* and *B. sphaericus* strains 1593 and 2362. Research on this field really began in April, 1977 when the WHO initiated a workshop on the Biological Control of Insects at the WHO Mosquito Control Research Unit in Kaduna. That workshop recognised some priority areas for research into biological control of insects (WHO, 1977) viz;

(a) Isolation of potentially useful biological control agents against medically important insects.

(b) Identification and characterization to the degree possible and in collaboration with an international network established by the WHO.

(c) Studies on the efficacy of microbial agents against insects of medical importance.

(d) Safety testing against laboratory mammalian models.

(e) Studies on the mass production of microbial agents in national institutions emphasizing locally available technology and material as media.

(f) Conduct of small-scale field trials (Stage III) against important sectors within the country, with agents which have already been tested elsewhere and which satisfy all necessary safety requirements set by international bodies.

Research on the biological control of mosquitoes in Nigeria received great stimulus from that workshop, and ever since, activities have shifted Southwards to Anambra State notably the University of Nigeria, Nsukka and the Anambra State University of Technology. All these activities have received support essentially from the TDR.

At the Mosquito Control Research Unit of the WHO in Kaduna, Dr. Prasertphon worked on *Bacillus thuringiensis* var. *israelensis* (B.t.i.) on a preliminary small field trials. His results, though unpublished, showed a high kill of mosquitoes. He did not report any untoward effect on non-target organisms associated with the mosquitoes.

At the University of Nigeria, Nsukka, several non-spore forming pathogens of mosquitoes were isolated but were not developed for obvious reasons. The unit shifted emphasis to spore formers, and obtained an isolate CCBC 2217 which was found to be closely related to the *B.t.i.* in use (Ejiofor, 1983). The unit further centred its research efforts on the development of local media for the growth of *B.t.i.* using 20-l bench fermentors. Five of such media which contain local legumes, meat extracts and dried cattle blood were tested in the laboratory and the field and the organisms growing on them were found to be as effective in killing mosquito larvae as the original preparation "IPS 78" obtained from Institute Pasteur (Obeta and Okafor, 1984).

The unit also tested commercial preparations of *B.t.i.*, BACTIMOS from Biochem. Inc. and TEKNAR from Sandoz Inc. against rice field *Culex* and *Anopheles* species both in the laboratory and in the field. Primary powders of *B. sphaericus* 1593 and 2362 were also tested against *Anopheles* and *Culex* species breeding in open drains and the oxidation ponds of large sewage treatment plants. In all cases of the trials, no untoward effect was observed against any of the non-target organisms associated with the mosquitoes (Ejiofor, 1983; Ejiofor and Okafor, 1986a,b).

At Anambra State University of Technology where similar fermentation studies on local media are going on, emphases are on (i) production of suitable local formulations, (ii) isolation and development of new strains and (iii) study of rice field microbial flora as an initial step toward cloning *B.t.i.* and *B. sphaericus* genes into them. In respect of item (iii) arrangements are underway for collaborative research with other laboratories elsewhere.

A National Workshop on the Control of Pests and Disease Vectors in Nigeria was held from the 21st to the 25th of February, 1988. This workshop was expected to deliberate extensively on the biological control of such vectors as mosquitoes. It is hoped that a new impetus will be given to research on biological control of mosquitoes at the end of the workshop.

FUTURE PROSPECTS OF BIOLOGICAL CONTROL OF MOSQUITOES IN NIGERIA

Since chemical insecticides are losing their popularity because of reasons already stated, tested biological preparations containing *Bacillus thuringiensis israelensis* and *B. sphaericus* could be used individually or in integrated control programmes against mosquitoes in Nigeria. Apart from the known efficacy of these bacilli against Nigerian mosquitoes, *B. sphaericus* has also demonstrated the ability to survive and recycle in the Nigerian environment, thus providing prolonged control (Ejiofor and Okafor, 1986b).

Raw materials like maize, leguminous seeds, rice, mineral supplements, brewery wastes and even soya bean which are suitable for local production of these bacilli abound in Nigeria. This situation will definitely obviate the usual problems attendant upon importation of industrial raw materials following the current global economic crunch. Besides, the expertise for the production and formulation of the bio-insecticides exists and is being improved upon. As already stated the ecology of Nigerian mosquitoes is fairly well-known.

Two major obstacles, however, still remain to be surmounted. The first is awareness both by the public and governments of Nigeria. The public including even many scientists are still sceptical about spraying "germs" in the environment all in the name of controlling mosquitoes. They would rather have mosquitoes or the poisonous chemical insecticides than have the "deadly germs". If the attention of the governments could be sufficiently attracted, public awareness campaigns could be intensified. The second constraint is financial and material support for the workers in this area of biological control. It has not been possible to embark on large-scale production and formulation of these bio-insecticides because enough awareness has not been created to attract entrepreneurs, and research funding has been greatly inadequate. With adequate funding both from the governments and international organisations, biological control using entomopathogenic bacilli might well hold the trump card for the war against mosquitoes and mosquito-borne diseases in Nigeria and elsewhere in the coming decade.

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