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TOPIC:

MAN'S STRUGGLE WITH INSECTS: HE STOOPS TO CONQUER

By

PROFESSOR (MRS.) W. A. MAKANJUOLA

MAN'S STRUGGLE WITH INSECTS: HE STOOPS TO CONQUER

An Inaugural Lecture Delivered at the University of Lagos Main Auditorium on Wednesday, 29th February, 2012

by

PROFESSOR (MRS.) W.A. MAKANJUOLA

B.Sc., M.Sc., Ph.D (Ibadan)

Professor of Applied Entomology and Pest Management

Department of Zoology
Faculty of Science
University of Lagos

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PREAMBLE

The Vice-Chancellor, Deputy Vice-Chancellor (Academic and Research), Deputy Vice-Chancellor (Management Services), The Registrar, The Provost, College of Medicine, Dean of Science and other Deans here present, Members of Senate, Principal Officers of the University, Heads of Departments, My Colleagues, University of Lagos staff, My dear students, Invited Guests, Members of the Press, Distinguished Ladies and Gentlemen.

Give unto the Lord, glory and strength
Give unto the Lord, the glory due to His name
Worship the Lord in the beauty of holiness
O Lord, my God, I will give thanks to you forever.

Today, Wednesday, the 29th of February, 2012, I stand before you all on my '15th' celebrated birthday to tell of how God planned my path to be an academic in the research area of Applied Entomology and Pest Management. I am one of those who wanted to read Medicine because I believed I had a calling to help the sick. This belief was strongly fueled by sentiments which arose when I lost my dad and immediate younger sister to medical negligence. Indeed, through nurturing of my new found passion, I was determined to become a doctor someday, somehow. That was my dream, and as noble as it was, God veered me away from it and fitted me with another career, which has turned out to be my best fit. Hence today, I am an entomologist.

Getting to where I am today has been a long and eventful journey in which contributions to the world of Applied Entomology and Pest Management have marked my path. These contributions have arisen from a primary focus on what I believe to be of paramount concern in pest management- the on-going struggle between man and insect pests.

Mr. Vice-Chancellor Sir, indeed man has been in an unending battle with insects as they both struggle to gain supremacy over the earth. With the insects struggling to devour man's food, suck his blood and infect him with various diseases, man is faced with an urgent and struggling need to resist their attack.

Now the genesis of this struggle can be traced to Genesis 3:17, where God cursed the ground because of man's sin and said that in sorrow shall he begin to eat of it all the days of his life. Hence ever since man's fall from his grand, privileged standing, he has been left to fend for himself through cultivation of crops. This has thus brought instability into an otherwise stable ecosystem and as we would see later in the lecture, has invariably triggered various insect problems which man has been forced to contend with.

Therefore, it is safe to say at this point that due to man's fall out with his maker, he has been forced to stoop from his former grand standing of absolute control to levels where he has to engage in continuous battle with these crawling and flying creatures. It is only by research and developing alternate strategies that will enable him escape from their menace.

Hence in this lecture, whilst highlighting my key contributions to the management of insects, I will take you through my journey into the world of Applied Entomology and Pest Management.

IN THE BEGINNING...

As noted earlier, I am an entomologist today because of landmark events that shaped my life and aspirations at a very young age. At the age of seven, I arrived in Nigeria for the first time, alongside my mum and two younger sisters. However, soon after, with both my parents working at University College Hospital (UCH), Ibadan, disaster struck; not once but twice.The first strike occurred following a successful medical operation on my sister. The oxygen supporting her breathing finished and the unexpected happened, she passed on. A few months later, my father, a medical doctor who was brought up and sponsored to Trinity College, Dublin by his aunty, Madam Ayinke Dada also passed on through negligence involving wrong blood transfusion. Indeed this was very tragic for my father's family who were still basking in the delight of having the first Doctor in the family. As for my mother, arriving into the country for the first time, this was definitely catastrophic.

With all of this at the back of my mind, I developed a bias for Science and was certain I would study medicine in order to fill the gap left behind by my father. However by divine providence, I was not to take that path. I lost my opportunity to study Medicine at University of Nsukka, when I fell short during the entrance interview. I then went in for A-levels but failed to make Physics, a subject which I had always viewed as an easy pass. Hence I was left with an admission into the University of Ibadan to study Agricultural Biology. This in turn left my family disappointed because of their great expectations to see me carry on the torch of my father's career line. Despite this upset, I hurriedly went on to grab the academic life line offered to me in Agricultural Biology. I took the line and never looked back even when my family expected me to do a change of course after my first year in the University. Indeed what we were all ignorant of then was that God was ordering my steps along a path that will plant me in classrooms and

laboratories where I will teach, research and develop into the entomologist that I am today.

At this junction, the burning question to the lay man must be this- 'Who exactly is an entomologist?'

WHO IS AN ENTOMOLOGIST?

An entomologist is a specialist who studies different aspects of an insect's life and the role they play within the ecosystem. Now, for you, it may be impossible to imagine that anybody will be interested and willing to spend his/her life running after insects. 'Towards what end?' you may wonder.

Well, people that nurture such questions are obviously ignorant about the great importance that these crawling and flying creatures in question, are to mankind. Indeed entomologists do not just study insects for the mere sake of academics; rather they do so because of the relevant influence they have on man.

WHAT ARE INSECTS?

First, it must be established that not all invertebrates or small hard shelled animals are insects. For example spiders, mites and ticks are not insects although they are all Arthropods because they have an exoskeleton. What then are insects? Insects are animals without backbones (invertebrates). What they have are exoskeletons which can be divided into head, thorax and abdomen. All of their walking legs are found only in the middle region – the thorax – with one pair each on the three segments making up the thorax. All insects have a pair of antenna. Not all insects have wings, but all invertebrates with one or two pair of wings are insects (Plate 1).

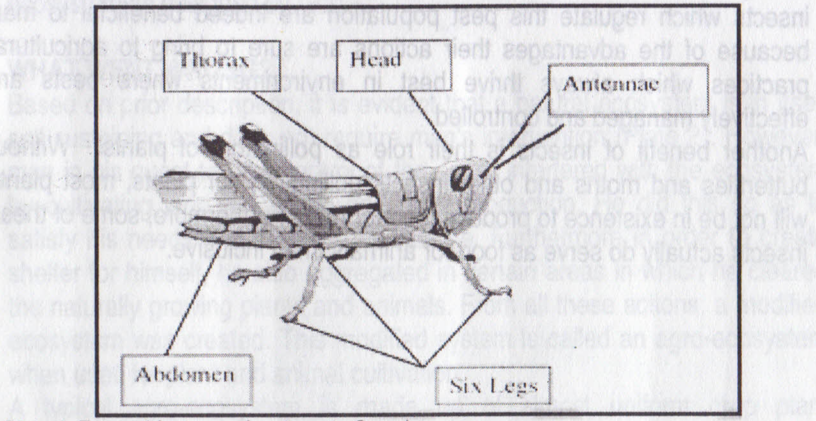

Plate 1. *External features of an insect - Grasshopper*

Today, with insects living in every nook and cranny and representing 70% of all living animals, more than one million of its species are known with many more yet to be identified.

ARE INSECTS BENEFICIAL TO MAN?

The popular misconception is that most insects are pests which transmit diseases to man, animals and devour his crop plants. However contrary to this school of thought is the reality that though some insects are indeed pests, majority of them are actually of no adverse consequence to man. Indeed not only are many of them harmless, they are also of great significance within the ecosystem.

It will be wrong to assume that we are all familiar with the term 'ecosystem', hence before going any further; I will put a definition to it. An ecosystem is a biological environment consisting of all organisms living in a particular area as well as the non-living (abiotic) physical components of that area; such as the air, soil, water and sun; with which the living organisms interact with (Campbell *et. al.*, 2009). It consists of different kinds of interacting organisms; insects and man inclusive; influenced by the abiotic and biotic factors in their environment. A natural ecosystem is a complex, dynamic but stable system in which nutrients and energy are continuously recycled. In an ecosystem, there is a food chain within which the density dependent factors, insects inclusive; act as predators and parasites which regulate pest population depending on the environmental conditions.

The described interactions bring about natural selection and in collaboration with other environmental factors, the population is maintained within certain upper and lower limits. This automatically guarantees a balance in nature as pests are prevented by predators and parasites, from increasing into outrageously large, harmful numbers (Figure 1). Hence it is obvious that the insects which regulate this pest population are indeed beneficial to man because of the advantages their actions are sure to bring to agricultural practices which always thrive best in environments where pests are effectively managed and controlled.

Another benefit of insects is their role as pollinators of plants. Without butterflies and moths and other insects pollinating our plants, most plants will not be in existence to produce food for man. Furthermore, some of these insects actually do serve as food for animals, man inclusive.

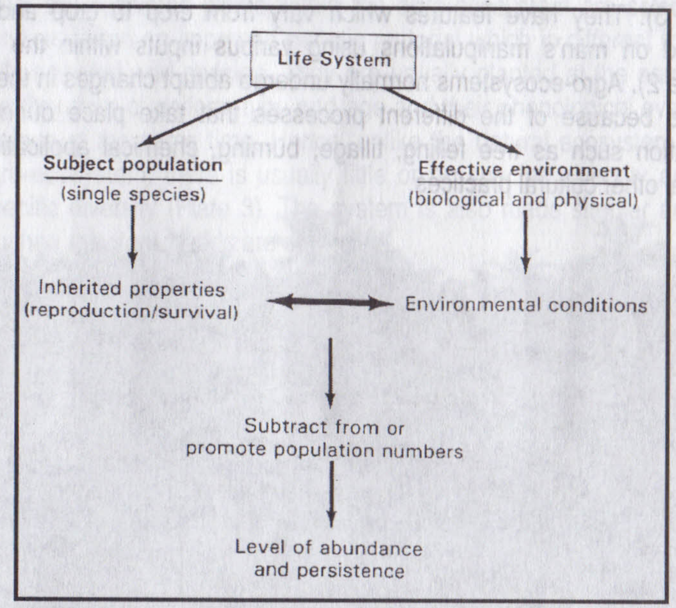

Figure 1. *Diagram of the determinants of insect abundance in a life system. Source: Pedigo, (2000)*

From the above, it can be concluded that it is indeed wrong to categorize all or most insects as awful creatures, good only for evoking harm. This is because within the perfect ecosystem, not only are most of them useful but even the few harmful ones that pose as pests are effectively controlled and managed by their predator and parasitic counterparts. Now, such was the ecosystem as designed by God.

WHAT WENT WRONG?

Based on prior description, it is evident that a natural ecosystem is in itself self-sustaining and does not require man's intervention (Plate 2). However, man in his quest to take control of the earth, interfered with the ecosystem by cultivating land for animal and plant production. He did this so as to satisfy his needs and improve his lifestyle. Furthermore in order to create shelter for himself, he also aggregated in certain areas in which he cleared the naturally growing plants and animals. From all these actions, a modified ecosystem was created. This modified system is called an agro-ecosystem when used for plant and animal cultivation.

A typical agro-ecosystem is made up of almost uniform crop plant population, in which other members of community such as weed and microbes interact with the physical factors within the specific environment

(Plate 3). They have features which vary from crop to crop and which depend on man's manipulations using various inputs within the system (Figure 2). Agro-ecosystems normally undergo abrupt changes in the micro-climate because of the different processes that take place during plant cultivation such as tree felling, tillage, burning, chemical application and several other cultural practices.

Plate 2. *A natural ecosystem - Rainforest*

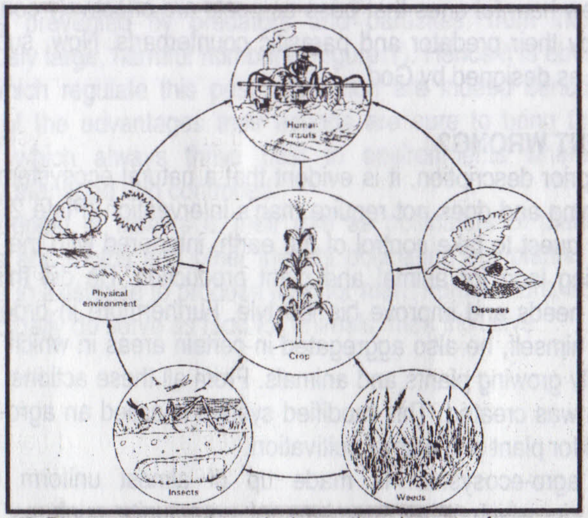

Figure 2. ***Diagram showing the major interacting elements of agro-ecosystem.***
Source: Pedigo, (2000)

Note that the cultivated plants within the agro-ecosystem are selected by man and are often an improved genetic material which is different from the naturally selected wild species. They are usually planted at the same time and are therefore of uniform type and age and their phenological event also takes place at the same time. Hence, unlike the natural ecosystem, within the agro-ecosystem, there is usually little or no species diversity and little intraspecific diversity (Plate 3). The system is also made simpler and less stable when resultant weeds are controlled.

Plate 3. *An agroecosystem*

At this junction, I want to point out that as the ecosystem diversity decreases, most host specific insects are denied the comfort of their natural habitat which invariably results in their migration in search of food or simply die from want of food. Also, the insect pests which live on the dominantly cultivated uniform crops begin to breed uncontrollable due to the easy availability of their host plants and domestic animals which serve as their food. This automatically increases the risk of damage they can wrought on their host plants especially the types cultivated with the aid of fertilizers which make the crops more succulent. This risk of damage is especially very high because natural environmental features which would have curbed the pest population level have been manipulated by man in their favour. Also rendered ineffective in the regulation of insect pests are the predators and parasites which would have also been greatly outnumbered by their rapidly increasing population.

From this we can see that man's quest for occupational utilization of the earth has created insect problems by developing agriculture which makes the insect's environment more favorable than initially designed. Hence this interference has made otherwise harmless insects become harmful. Now man's attempt to manage the erupted problem through the use of insecticides as a control mechanism against the emerging insects has brought another backlash within the ecosystem. This is because the insecticides, which are chemicals, are poisonous not only to the target insects but to other animals and man as well. Insecticides as well as the fertilizers, pollute the groundwater, streams, rivers and ocean thus creating other problems in the ecosystem.

In summary, unlike the diverse, stable, natural ecosystem which requires no energy input from man, an agro-system needs a lot of energy input in order to maintain man's unnatural farming system. This created unnatural condition exposes crops to unusual high density of pests which ultimately lowers the global outputs from the agricultural sector of a nation's economy. The challenge to agriculturists is to find ways of minimising the negative impact on the ecosystem.

OVERVIEW OF CROP MANAGEMENT IN NIGERIA

Up till the late 60's, the mainstay of Nigeria economy was production and export of many cash crops namely: cocoa, palm kernel, palm oil, rubber and groundnuts. During this early era in the history of nationhood, the agricultural sector was mainly dependent on output of peasant farmers who produced about 95% of the nation's food needs and accounted for 70% of exports (Lawal, 1997). As the nation becomes more and more dependent on crude oil export, the importance of agricultural sector declined and this has continued to this day that the sector accounts for less than 5% of the nation's GDP (Olagbaju and Falola, 1996).

Now with a passion rooted in a desire not to see the agro-sector making the same mistake of the oil sector, this lecture will subsequently emphasize on what I believe is at the root of our detrimental agro-sector- **Inefficient pest management**. I say inefficient pest management because I believe that, thanks to man's interference, it is the outrageous and uncontrollable increase in pests that makes our present agricultural practices tedious and inefficient and subsequently deters our farmers from farming the land.

The Government Steps In...Or Not

Before going any further, let's briefly look at the government's input in the matter at hand. This is because the pest challenge is so huge that, like it or not, we need the government's aid in managing it right.

In the seventies, there was the Operation Feed the Nation, the brain work of the then Head of State, General Obasanjo. Despite the intentions of this project to alleviate poverty, food still fell short of supply in the midst of its implementation. Again there was the Green Revolution Program, a major agricultural policy of President Shehu Shagari administration which was the fourth national development plan introduced in the 1980's to step up production, so as to flood the nation with food for its citizens and thus make it self-sufficient. The introduction of modern technology into Nigeria's agriculture, largely through modern inputs such as high yielding varieties, fertilizers and tractors was then proposed. However in this particular described project, the emphasis was to introduce high yielding varieties without considering its susceptibility to field and storage pests and of course we all know what the outcome was.

Then there was the National Rolling Plan for 1996 – 1998 which proposed that by 2000, Nigeria would be able to feed her population and also develop capacity to process raw materials both for local industries and export. This proposal is yet to be realized.

In 2001, the government launched a new agricultural development policy to

1. achieve self sufficiency in bank food supply and attainment of food security;
2. increase production of agriculture raw materials for industries;
3. increase production and process of export crops using improved production and processing technologies;
4. generate gainful employment;
5. rationally utilize agricultural resources from drought desert encroachment, soil erosion and flood and general preservation of the environment for sustainability of agricultural production;
6. promote increased application of modern technology to agricultural production; and
7. improve the quality of life of rural dwellers (Ogen, 2007).

Under the new policy, the Federal Government was to be responsible for the control of pests and diseases of national and international significance, the promotion of integrated disease and pest management, and the establishment and maintenance of virile national and international animal and plant quarantine services. An excellent policy but since 2001 how far have we gone? Is it a case of square pegs in round holes or vice-versa? Eleven years after, what do we say? Have we felt the impact of the government's policy to produce food for its people?

Really, now is the time for the government to learn from the past and move our agro-sector forward. However in order to move forward, government would need to get entomologists involved in policy making and its implementation.

The introduced government policy on insect control and pest management is a step in the right direction of addressing issues of concern. It is my intention to use this lecture, based on my research findings, to make some meaningful contributions in our quest to improve pest/vector management in the country.

PEST MANAGEMENT IN NIGERIA

In Nigeria, the pest control concept is not often practiced because control measures must not be taken unless it is established that an insect cannot be biologically controlled by its natural enemies (parasites and predators) and will therefore cause economic damage. Deliberately or not, this concept signifies the importance of biological control in pest management.

Biological control is a deliberate act of man using the natural control agent within the environment of the target organism to regulate its population. It does not eradicate but regulates the population which is at equilibrium with the carrying capacity of the particular environment. Now the magnitude of the importance of biological control was impressed on me in 1975 when I was a student.

My supervisor then (Prof. J.A. Odebiyi), a professor of entomology, observed that some leaves were rolled up on some of the Okra plants in the University's biological garden. Our investigation into this curious phenomenon revealed that there were some insect larvae within the rolled leaves. To our surprise, we were unable to locate eggs on the plants. But searching through literature I found out that some larvae of some *Lepidoptera* were responsible for the rolling of the leaves. It was then suggested that I study the insect's biology by collecting the various sizes of the larvae in the field and bring them into the laboratory for rearing. Hence I collected and reared the larvae and finally adults were obtained. The adults were identified as cotton leaf roller, *Sylepta derogata* Fabricious (Plates 4 and 5). They laid eggs and their various larval stages were collected. The

respective mean width of each larval instar head capsule was measured and the number of larval instars determined using Dyar's law.

From the described study, it was revealed that these larvae fed on leaves causing defoliation and rolled the leaves while they developed into pupae after which the adults finally emerged. It was also interesting to further discover that the larvae had parasitic eggs deposited within them which caused them to be covered with a cluster of white pupa after a few days. The adults which emerged from these pupae were then identified as *Apanletes* sp. parasitic wasp, belonging to order hymenoptera (Plate 6).

Now the revelations from the above study made me understand for the first time the role of natural enemies in pest management. The number of parasitic wasps which emerged as the natural enemy of the larvae were numerous and I felt that if it was not interfered with, they would effectively control and manage their host *Sylepta derogata*. Hence based on the pest management concept, it is evident that with the biological control of the larvae by its natural enemies, there might be indeed no need for man to interfere with his own non-biological control measures.

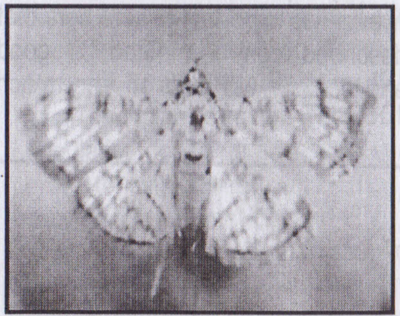

Plate 4. *Sylepta derogata* adult

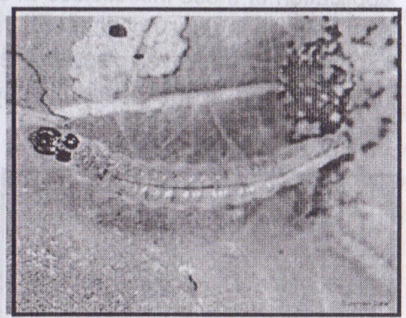

Plate 5. *Sylepta derogata* larva

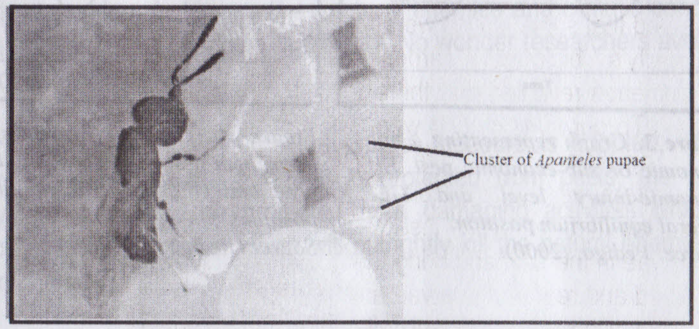

Plate 6. *Apanletes* sp Parasite of *S. derogata*

When Does Man Initiate Control Measures?

With us now aware of the place of biological control in pest management, the next pressing question is this - **At what point do we apply other control measures e.g. chemical control to effectively curb economic loss?** As will be subsequently described, we can only know this by accurately estimating economic damage.

The status of a pest can only be determined through pest density i.e. the number of insects present in a unit area. Knowing the pest density then enables one to determine **Economic Injury Level (EIL)** which is an indicator that signifies if pests have been controlled below a level of damage that can be tolerated. Economic Injury Level (EIL) can thus be defined as the lowest population density that will cause economic damage. It is the critical density where crop loss due to pest damage is equal to cost of control measure. Measures which utilize insecticides must therefore be taken before pests reach EIL and the best level at which to take them is the **Economic Threshold level** (ET) which is the level below the EIL. The timely application of these insecticides at ET is very important in ensuring that the pest population does not attain EIL. However it is important to note here that in order to effectively apply the described control method, a good understanding of the pest's biology and ecology will also be very much needed (Figures 3 - 6).

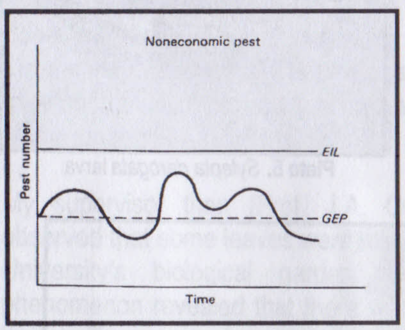

Figure 3. Graph representing a non-economic or sub-economic pest. EIL, economic-injury level and GEP, general equilibrium position.
Source: Pedigo, (2000).

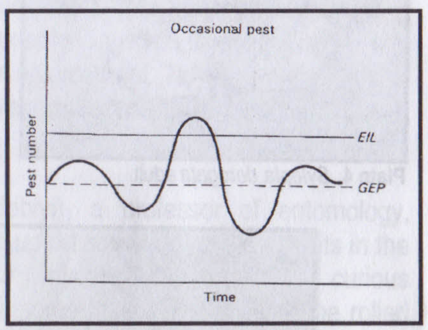

Figure 4. Graph representing an occasional pest. EIL, economic-injury level and GEP, general equilibrium position.
Source: Pedigo, (2000).

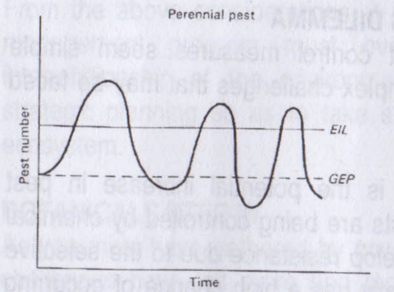

Figure 5. Graph representing a perennial pest. EIL, economic-injury level and GEP, general equilibrium position.
Source: Pedigo, (2000).

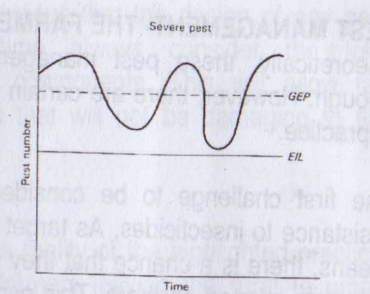

Figure 6. Graph representing a severe pest. EIL, economic-injury level; and GEP, general equilibrium position.
Source: Pedigo, (2000).

Now it will interest you to know that most entomologists/ecologists are not inclined to carry out research in this area of pest management because, with emphasis on number of papers for promotion, it will take many years to obtain the required numbers if one is to achieve meaningful results. The need for many years of intense study can be attributed to a dynamic **General Equilibrium Position (GEP)** within a dynamic ecosystem with an ever changing climate. The GEP, which is the average uninterrupted population density of an insect over a long period of time, must be studied in order to establish EIL and ETL. The pest status of insects can only be classified based on EIL and ETL, in relation to the position of GEP. It is pertinent that a good understanding of the pest's biology and ecology are needed to adopt strategies of control that will yield meaningful results. Hence embarking on these studies will indeed prove to be challenging as it will be seen that population fluctuates around a mean due to influence of density dependant factors such as natural enemies and climatic conditions which appears to be changing drastically. No wonder researchers avoid this area of research.

Now in summary, no matter what control measure is adopted, what is important is that as the farmland is protected from pests, the natural ecosystem must also be protected from damaging activities which will reduce its effectiveness or which will outrightly kill the natural enemies that control the pest.

PEST MANAGEMENT- THE FARMER'S DILEMMA

Theoretically, these pest management control measures seem simple enough. However, there are certain complex challenges that may be faced in practice.

The first challenge to be considered is the potential increase in pest resistance to insecticides. As target pests are being controlled by chemical means, there is a chance that they develop resistance due to the selective pressure exerted on them. This especially has a high chance of occurring when the insecticide spraying regime is carried out year in, year out. The problem is further aggravated when trying to tackle this identified resistance, the farmers' normal practice is to increase insecticide dosage at greater frequency of application which result in pests' resurgence. In the process of all this, insectivorous predators and parasitic species also get killed because insecticide dosage is increased. The pressure of the natural enemy is therefore lessened leading to secondary pest outbreak which was formerly under control.

Another challenge faced is the potential harm to insect pollinators and wildlife because they also are likely to become recipients of the insecticide's dosage either through direct exposure or through feeding. This results in mortality and reduction in the population of such pollinators and wildlife.

Beyond the threats thrown in the face of pollinators and wildlife, it is also worth considering the fact that man could also be a possible victim. We must have all read in Newspaper reports of how families have been killed from consuming meals contaminated with insecticides. Such incidents occur when certain of these insecticides; mainly the organochlorines and organophosphates; remain as poisonous residues in edible plants and animals. These chemicals may affect their physiology which will in turn grievously affect the animals and humans that consume them. Attempts have been made to solve this challenge by ensuring that there is a fixed minimum period between the last insecticide application to harvest or slaughter of cattle and other livestock and the time of consumption.

Another challenge for consideration is the residue problem of persistent synthetic chemicals within the tropic level. The chemical could end up accumulating and biomagnifying along the food chain. They could also find their way to the soil and water and spread to other locations from the site of application, thereby having a negative effect on the quality of the environment.

From the above considerations, it is obvious that the design of any pest management program must over time always consider the total interrelationship of the environment's components. This will allow fair strategic planning so as to take steps that will not be damaging to the ecosystem.

BOTANICALS STEP IN

As you must have gathered by now, the reality of the highlighted practical challenges have left more and more farmers leaving the rural to urban areas, looking for other jobs. Agriculture obviously has become unattractive due to the high losses incurred due to insect pests, because farmers are unable to engage in effective pest management practices. Moreover, beyond field control practices, due to poor storage facilities, even successfully harvested produce is damaged by insects. The farmer therefore considers it unprofitable to purchase quality seeds because they may be wasted in the long run when their resultant plants and produce are adversely affected by these pests. The very high cost and scarcity of insecticides that may be adulterated have also aggravated the situation. Furthermore, even when insecticides are available, they may be expired.

It has therefore become pertinent to investigate an alternative method to solving the problem arising from the use of synthetic chemicals which are so damaging to the ecosystem apart from being very expensive to the peasant farmer.

It is from this perspective that I veered into the use of botanicals in the control of stored product pests. The use of botanicals may actually succeed in providing a simpler and cheaper means of pest management that is affordable to the peasant farmers who are responsible for the production of most agricultural crops in our country.

THE BOTANICAL ADVANTAGE

Nigeria is endowed with rich vegetation of which many components within plants may have active insecticidal ingredients for the control of pests. These ingredients are the plants' chemical defenses against insects. When they are extracted they are commonly referred to as **botanicals**. They have long been used as a traditional method in controlling insect pests and may provide the farmer with locally available, biodegradable and inexpensive methods of protecting his produce from insect infestation. Botanicals are environmentally friendly, less hazardous chemicals unlike synthetic chemicals which have residues lingering for a long time within the ecosystem. Furthermore, while the residue of synthetic chemicals do impact negatively on the non-target insects which are beneficial to man, botanical's residue do not endanger soil, water supply, man or wildlife. Generally, with the exception of a few botanicals like nicotine, botanicals are less toxic to mammals. Some of these botanicals are of medicinal and culinary use, thus further indicating that they are relatively safe to man.

THE NEEM SOLUTION

Mr. Vice-Chancellor Sir, it is with the above in view that I decided to research on natural products with emphasis on botanicals as a pest control measure. The neem plant, scientifically known as *Azadirachta indica,* was my choice candidate. It is a medicinal plant that is widely grown in Nigeria and used by man for various ailments. It was chosen because unlike synthetic insecticides, it has very desirable properties. It is considered almost non-toxic to man and animals and it is completely biodegradable. The neem plant is hardly known to be infested by insects Bhatia and Sikka, (1957) and is known to have antifeedant or repellant effects (Leuschner, 1975). These advantageous properties stimulated my interest and I was able to get support of a German Entomologist Dr. Leuschner, who secured a fellowship grant by International Institute of Tropical Agriculture (IITA), Ibadan to pursue a research on neem as a protectant against some storage insect pest. Before I proceed any further, I must mention that what was new and original about my research was the fact that very little research were carried out then using neem to control stored product pests under field conditions. My contributions in this area are herewith presented.

Extracts of neem leaves and matured kernels were prepared using a simple method that will be feasible for any peasant farmer (Makanjuola, 1989). Formulations used were water and methylated spirit. The aim was to develop a method of extraction that will be made available for farmers' regular use. The extract was used on major pests of cowpea- *Callosobruchus maculatus* (Plate 7 and 8), maize – *Sitophilus zeamais* (Plates 9 and 10) and sweet potato – *Cylas puncticolis.* I found out that all extracts of neem leaf and seed significantly reduced oviposition, percentage of hatched eggs and adult emergence of *C. maculatus* on treated cowpea. I was able to show that neem acts as an oviposition suppressant, ovicide and protected cowpeas from *C. maculatus* damage for five months under field trials (Tables 1 and 2). However, the extracts were not as effective in controlling the other two species of insects; *Sitophilus zeamais* (Plates 9 and 10) and *Cylas puncticolis* from maize infestation. While it had no effect at all on *Cylas puncticolis* (Table 3), it was however effective in suppressing *S. zeamais* population build up suggesting that the formulation may have some application as a control agent of *S. zeamais* sp.

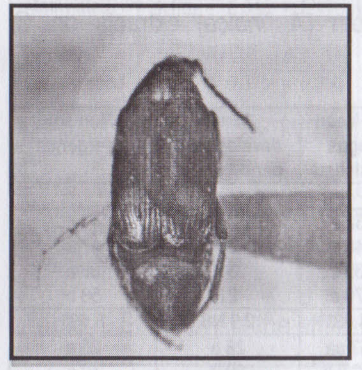

Plate 7. *Callosobrchus maculatus*

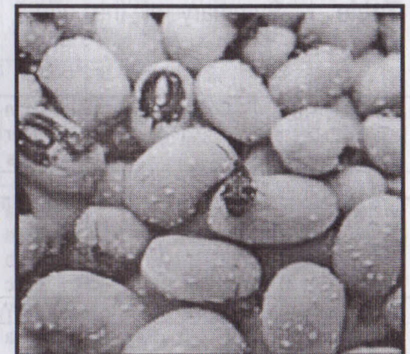

Plate 8. *Infested cowpea riddled with eggs*

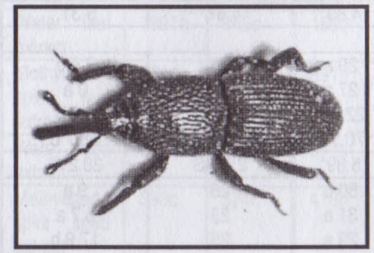

Plate 9. *Sitophilus zeamais*

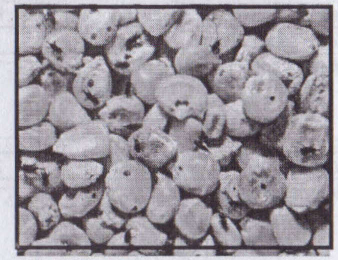

Plate 10. *Damaged maize grain.*

The results also revealed that the aqueous seed extract gave the best protection to cowpea and maize than the other formulations. Insect behavior was also observed to be important in determining the effectiveness of the extracts acting as contact and not as a systemic poison in that both *S. zeamais* and *C. punticolis* eggs were not affected since their eggs were embedded within the maize grain and sweet potato tuber respectively, and not on the surface as in the case of *C. maculatus.* The extracts acted as contact and not systemic poisons because they could not control existing infestation since the larvae were well protected within the grain tuber.

Table 1. Summary of the effect of neem (*A. indica*) extracts on *C. maculatus*.

Treatment	Concentration (%)	Mean number of eggs	% Mean eggs hatched	Mean development period (days)	% Men adult emergence
Neem leaf extract					
Water	40	209 a	52 a	28	41 a
	60	200 a	48 a	24	47 a
	80	153 b	35 a	31	36 a
	Control	300 c	70 c	21	58 b
Variance ratio		0.43**	4.83*	2.9 NS	5.53*
Methylated spirit	40	107 a	57 aa	28 b	35 a
	60	126 a	52.5 b	29 b	49 a
	80	134 a	42.5 b	31 b	43 a
	Control	307 b	68.9 a	20 a	56 b
Variance ratio		10.71**	4.89*	4.87*	5.31*
Neem seed extract					
Water	40	45 b	29 a	28	3.9 b
	60	11 a	27 a	32	0 a
	80	23 a	22.9 a	32	2.8 b
	Control	213 c	70.9 b	24	58.7 c
Variance ratio		24.7**	5.89*	2.7 NS	28.2***
Methylated spirit	40	100 c	50 b	28	9 a
	60	39 a	31 a	29	6.7 a
	80	53 b	29 a	25	17.9 b
	Control	197 d	70 c	23	54.8 c
Variance ratio		16.9**	5.17*	0.9NS	15.5**

Each datum is a mean of 4 replicates. Percent adult emergence is a percentage of number of hatched eggs.
NS= not significant; *significant at 0.05%; **significant at 0.01%; ***significant at 0.001%.
Means followed by the same letter are not significantly different.
Source: Makanjuola (1989).

Table 2. Summary of the effect of neem extracts on *C. maculatus* in field trials

Neem formulation	Extract concentrates							
	100	80	70	60	50	40	Control	F-value
Population of C. maculatus after 5 months storage								
Water leaf extract	198b	179b	203b	197b	274c	258bc	3700a	838.8***
Methylated spirit leaf extract	189b	201b	256c	301d	379de	323d	3700a	604.01***
Water seed extract	45b	68b	73bc	71bc	103d	113d	3700a	946.56***
Methylated spirit seed extract	87b	89b	69b	93c	213d	205d	3700a	733.45***
Percent weight loss of cowpeas after 5 months storage								
Water leaf extract	1.18b	1.21b	1.34b	1.39b	1.31b	1.01b	25.3a	6384.8***
Methylated spirit leaf extract	1.11b	2.01c	2.17c	1.85c	3.12de	2.17d	25.3a	1080.4***
Water seed extract	0.61c	0.37b	0.30b	0.29b	0.58c	0.74cd	25.3a	8788.8***
Methylated spirit seed extract	0.73b	0.85c	0.66b	0.54b	0.89c	0.79c	25.3a	7334.78***

***Significant at 0.001. Means followed by same letter are not significantly different. Each datum is a mean of 10 replicates.
Source: Makanjuola (1989).

Table 3. Summary of the effect of neem extracts on *S. zeamais* in field trials

Neem formulation	Extract concentrates							
	100	80	70	60	50	40	Control	F-value
Population of S. zeamis after 5 months storage								
Water leaf extract	1291b	945c	158b	1013c	1379ab	1413a	1585a	3.18*
Methylated spirit leaf extract	884d	1245ab	891d	1123c	1279ab	1381ab	1585a	7.41**
Water seed extract	375bc	238d	313c	518b	394bc	435b	1585a	113.79***
Methylated spirit seed extract	398c	374c	418b	391c	487b	476b	1585a	99.81***
Percent weight loss of maize after 5 months storage								
Water leaf extract	32.98	32.79	32.47	32.58	32.72	32.83	33.1	1.1 NS
Methylated spirit leaf extract	33.30	32.87	32.88	32.92	32.99	33.16	33.1	0.89 NS
Water seed extract	3.51c	8.71bc	8.33c	9.47b	8.11c	8.61bc	33.19	11.88***
Methylated spirit seed extract	9.43bc	7.21d	10.43b	9.39bc	7.49d	8.88cd	33.19	9.77***

NS, not significant; *Significant at 0.05; **Significant at 0.01; ***Significant at 0.001.
Means followed by same letter are not significantly different. Each datum is a mean of 10 replicates.
Source: Makanjuola (1989).

The published work in the renowned international Journal of Stored Product Research stimulated a lot of interest from various researchers in North Africa, Asia and Europe. Hence I was invited to share my findings with other scientists at an international conference in Western Germany. Indeed unlike most studies on botanicals, I actually undertook trials in the field to evaluate the effects of environmental factors on the extracts efficacy.

Besides my own work, a lot of other works have been carried out in Nigeria on the use of botanicals in the control of pests. However, though all our works have shown that there are potential benefits in substituting important synthetic materials with locally manufactured equivalents, implementation efforts are still lacking. Hence the Nigerian government, the private sector, farmers and the academia can and should all play their role at a much intensive and larger scale. A substantial research investment particularly from the government can result in landmark production of natural agro-chemicals. Nigeria being so blessed and endowed with natural human resources as a nation, it is necessary she harnesses these God given gifts to her advantage and use.

FROM NEEM TO RESISTANCE VARIETIES

Thereafter, my research efforts shifted and the use of **host resistance in pest management** became my objective/goal.

Resistant Varieties in Pest Management

For better understanding of the word resistance in pest management, I will first take you through some familiar everyday occurrences. Think back to when your family (or any other family) experienced a chicken pox outbreak. While some family members were either severely or moderately brought down by the disease, some were not affected at all. We can describe the people not affected as resistant, while those who suffered severely under the same environmental condition as highly susceptible. This is the same with plants. Plant hosts may be highly susceptible, moderately susceptible or resistant to an insect injury. Plants that resist insect injury do so by avoiding or tolerating the insect. Other plants though injured by the insect, recover from the injury which would have otherwise had significant negative impact on them. These reactions from the resistant plants are very unlike their non-resistant counterparts which would have experienced great damage when infested by the same population of insects under similar environmental conditions. The variation in susceptibility of a host plant to insect injury are due to the differences in the genetic makeup of the plant.

Based on the described resistance modes, genetic resistance is classified into three; **non-preference, antibiosis and tolerance.**

- Non-preference (antixenosis) is when a plant variety lacks one or more of the preferred characteristics of the pest or has some chemical which makes it unattractive to it. In such instances, the insect does not utilize the plant for oviposition, food or shelter.
- Antibiosis which is the preferred mechanism occurs when the metabolism of the insect is adversely affected due to the intake of some of the secondary metabolites present in the plant. Deficiency in the quality and quantity of the primary metabolites may also affect the normal development of the insect due to imbalance of important nutrients such as amino acids.
- Tolerance is when certain plants have vigor that is able to withstand the population of pest infestation. In such cases, the plant is able to repair the tissues and recover from the injury.

From the described genetic resistance classifications, it is obvious that insect resistant is based on its morphological and/or biochemical characteristic which influence its behaviour and/or metabolism which in turn affects the degree of damage brought about by the insect utilizing the plant for oviposition, feeding or shelter. Therefore, it can be said that resistant traits are pre-adaptive and are as a result of the genetic make-up in the plant which is able to withstand the selective pressure of the insect population. However, it is important to point out at this junction that for genetically non-resistant plants, it is actually possible to introduce partial resistance through cross-breeding. This is an important strategic measure adopted during pest management because of the many advantages that accompany the use of resistance in pest control.

The use of resistant plant host brings about a cumulative effect over time in which the pest damage is significantly reduced without any negative impact on the ecosystem. The reliance on insecticides is reduced and the attendant adverse effects brought about by their frequent introduction into the agro-ecosystem are eliminated. Another advantage is that this approach has no negative impact on the plant, man or his interests. Furthermore resistance varieties can be incorporated into normal farming operations at no cost and once established has no cost implication to the farmer. In conclusion, resistance varieties are economical and environmentally friendly, thus meeting the goals of pest management.

COMPARING RESISTANCE OF LOCAL AND IMPROVED MAIZE VARIETIES

While breeding grain/seed crops, local varieties are often geared to meet consumer's preference for soft, sweet tasting and large sized grains: This preference is unfortunately similar to that of insects. Due to consumers' preference for quality grains and high yielding plants, farmers prefer the improved varieties to the local ones.

With this notion in mind, it became pertinent that a blind approach to food increase through increase in acreage cultivated or by introduction of high yielding varieties which are normally associated with increased susceptibility to insect damage, the adopted approach should be through reduction of crop susceptibility to insect infestation. This, we believed can be obtained through identifying those varieties; in particular the discontinued local ones; that are resistant. Our research emphasized and focused on the identification and evaluation of the resistance of the local and improved varieties in order to identify which ones were relatively resistant to insect infestation.

I was privileged to have been partly funded by IITA to screen 60 local varieties and 17 improved varieties of maize which were all obtained from the germplasm bank at IITA. The tests pests were *Sitophilus zeamais* and *Sitotroga cereallela,* which are the major insect pests that cause appreciable economic losses to stored maize. *Sitophilus zeamais* is the most important pest of maize in South West Nigeria while *S. cereallela* (Plates 11 and 12) is the most destructive insect of all cereals in Northern Nigeria. They both damage maize prior to harvest in the field and thereafter damage continues in storage. Losses due to insects in cereals may be in the tune of 50% (Abraham and Firdissa, 1991).

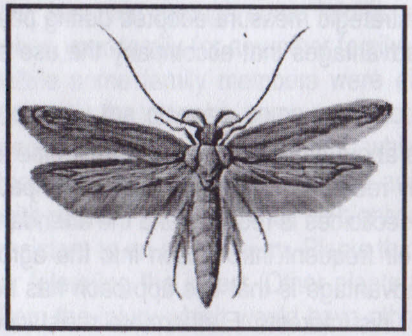

Plate 11. *Sitotroga cereallela adult.*

Plate 12. *Damaged by Sitotroga cereallela larvae.*

I first studied the lifestyle of *S. zeamais* and *S. cereallela* to improve my understanding of the object of concern after which laboratory screening of the 77 varieties for resistance to *S. zeamais* and *S. cereallella* were carried out. The susceptibility index (I) was then calculated using the parameters measured from the study

Sitophilus zeamais

$$I = \frac{\log(\text{no. of F1 adults})}{\text{Time taken to 50\% adult emergence}}$$

S. cereallella

$$I = \frac{\log(\%\ \text{surviving}) \times 100}{\text{Development time}}$$

My results showed that there was significant difference in the mean number of weevils emerging from the various varieties which ranged from 0.75 – 35.5 per 20g. There was also significant difference in developmental period which ranged from 33 to 60 days. Generally, those with prolonged developmental period had fewer F_1 adults emerging and vice versa except for Ikorodu and Adaduana which had low F_1 adults and yet short developmental period. The index of susceptibility ranged from 0.27 – 10.80 which reflected that the rate of insect population build-up was higher in the susceptible varieties than the relative resistant ones. Table 4 shows that the maize varieties were grouped into 4 categories; 11 varieties each fell into relatively resistant and highly susceptible category, while others were moderately susceptible (21) or susceptible (34). There was significant positive relationship between weight loss and index of susceptibility which implies that the higher the susceptibility of the variety to the insect, the greater the grain loss.

Table 4. Maize varieties grouped into classes of susceptibility to *Sitophilus zeamais* Mots. infestation

Relatively resistant (11)	Moderately susceptible (21)	Susceptible (34)	Highly susceptible (11)
BS3	Ekpuke	Agbor white	MSC opaque
Umunachi	Local composite	Idomi	Farz 25
NCA	Ogbomosho	Basambra	Okona
Ikorodu	Akwete white	Egbene	Farz 7
Obubra 9	Evboneka	Awgu 2	Mexica composite x PND TXUPNO
Adauana	Afo	Ekpoko	BS3 x Bomolocal
NCB	Lahalal	Bida 8	Kuru
Ikeja 2	Akure	Farz 34	C10 x TZPB
Ifunpa	Awka 3	Awgu 1	Biu yellow
Ashipa	Igala	Aburo 2	Badagry 1
Asoso-aburo	Asaba	TZP B	Egbana
	Akoka	Bori	
	Lagos white	Ekiti	
	Akamkpa	Farz 23	
	Kankran	Bende 1	
	Bida 6	Farz 27	
	Awgu 4	Opobo 1	
	Aburopa 4	Farz 17	
	Ipokia	Bende 3	

	Ikot-ekpene white	Aba 2	
	Ifo	Ahoada 3	
		Okesan	
		Uwep	
		Imogu	
		S_1 123	
		Badagry	
		Ikomi white	
		Afikpo 4	
		Farz 1	
		Aba 1	
		Bende white	
		Bomo local	
		Afikpo 5	
		Petu	

Source: Makanjuola and Odebiyi (1991).

The results obtained for *S. cereallela* showed high significant differences amongst varieties. Number of F_1 adults ranged from 1.75 to 15.75 while time for development ranged from 24.5 to 46 days. The relationship between F1 adult emergence and development time was not significant for *S. cerealella* but there was a positive relationship between weight loss and susceptibility of grain. Thirteen varieties each fell into relatively resistant and highly susceptible category while 28 and 23 varieties each fell into the moderately susceptible and susceptible category (Table 5).

Table 5. Maize varieties grouped into classes of susceptibility to *Sitotroga cerealella* Oliv. infestation

Relatively resistant (13)	**Moderately susceptible (28)**	**Susceptible (23)**	**Highly susceptible (13)**
Aburo 2	Badagry	Afrikpo 5	MSC-opaque
Bida 6	Farz 17	Afo	Farz 7
Lahalal	Okesan	Ifo	Bende white
Petu	Awka 3	C10 x TZPB	BS3 x Bomo local
Farz 34	BS 3	Ekpuke	Asaba
Afrikpo 4	Imogu	Ikom white	Biu yellow
Bomo	Bida 8	Kuru	Ikeja 2
Kankran	Egbene	Akwete white	Farz 25
NCB	Farz 23	Opobo 1	Ekpoko
Ipokia	Bende 3	Awgu 2	
Farz 1	Asoso-aburo	Aba 1	
Adaduana	Farz 27	Agbor white	Awgu 1
Idomi	Evboneka	Ashipa	Okona
	Badagry 1	Lagos white	Ahoada 3
	Aba 2	Ifunpa	Mexican composite - x - TUXPNO
	TZPB	Obubra 9	
	Ekiti	Akure	
	Akamkpa	Bori	
	Ikot-ekpene white	S_1 123	
	Ikorordu	Basambra	
	Awgu 4	Bende 1	
	Ogbomosho	Akoka	
	Uwep	Egbana	
	Umunachi		
	Igala		
	NCA		
	Local composite		
	Aburopa 4		

Source: Makanjuola and Odebiyi (1991).

Mr. Vice-Chancellor Sir, during the late season when maize was most susceptible to weevil attack, we carried out further screening of the 77 varieties in the field at IITA to investigate the general field resistance to *S. zeamais.* The experimental field was surrounded on three sides by old maize field with dry infested ears which served as source of infestation. Maize variety Farz25 – a highly susceptible variety was used as check and planted at every ninth row. At silking stage, ears were covered with ear bags to prevent cross pollination. The ripened tassels were covered with tassel bags which were used to collect pollen and also protect plant from cross pollination. The top ears were pollinated and the plants were left in the field until the ears matured, ripened and dried before harvesting. Random samples were collected and the length of husk cover over eartip and number of husk leaves were taken. The two parameters were scored and the product of the individual scores gave the quality of husk since both parameters were regarded as of equal importance. After husk rating, twenty ears per plot of each variety were dehusked and the number of adult *S. zeamais* recorded after 50 days. The mean number of weevils found at harvest ranged from 0.75 to 15.5 but fifty days after harvest the number had increased ranging from 2.75 to 116.75. The rate of increase of weevil ranged from 1.00 to 16.78. The varieties were grouped into four categories of susceptibility. Fourteen each were regarded as relatively resistant and susceptible respectively (Table 6).

Results showed that the level of initial field infestation does play an important role in the population build up in the store and that there was a negative and highly significant relationship between husk quality and all parameters except for rate of emergence (Table 7). Hence, good husk quality significantly resulted in lower infestation and consequently lower damage. This is because the husk covers acted as barriers to insect infestation. Some ears that were not fully covered suffered significantly higher infestation than those with long extended husk over tip.

With the establishment of the role of husk covers, it was then surprising to see that there were a few exceptions to the rule. Varieties such as Ifunpa, Awka3 and Ekpoko with low husk quality rating were amongst the most resistant (see Table 6). Indeed the rate of emergence of the insects from them was low in laboratory studies carried out earlier where they were categorized as relatively resistant. Furthermore despite Ikeja 2 having a low level of infestation at harvest due to its good husk cover quality, nevertheless the rate of infestation build up after harvest under field storage was high.

Hence, from this study, we were able to establish two facts (1) Grain quality is the major factor that confers resistance once infestation has been initiated and not the husk quality, (2) while husk quality is first barrier to infestation, if it breaks down then quality of grain becomes a more important barrier.

Table 6. Maize grouped into classes of susceptibility to *Sitophilus zeamais*

Resistant (14)	Moderately susceptible (25)	Susceptible (23)	Highly Susceptible (15)
Okesan	Lahalal	Akwete white	Mexican composite x TUXPNO
NCA	Lagos white	Obubra 9	Imogu
Badagry	Afo	Bori	A Egbana
NCB	Awgu 1	Farz 25	Biu yellow
Afikpo 5	Evboneka	Uwep	Afikpo 4
Awka 3	Bomo	C10 x TZPB	Ikot-ekpene-white
Ifo	Farz 7	Ashipa	Basambra
Umunachi	Agbor white	MSC-opaque	BS3 x Bomo-local
Ekpuke	Farz 17	Kankran	Ipokia
Ahoada 3	Akamkpa	Opobo – 1	Farz 23
Ekiti	Bende 3	Igala	Okona
Ikeja 2	Ekpoko	S_1 123	Bende 1
Petu	Akure	Ikorodu	Farz 34
Ifunpa	Egbene	Kuru	Farz 1
	Ikom white	TZPB	
	Agwu 4	Adaduana	
	BS 3	Bida 8	
	Aba 2	Farz 27	
	Aba 1	Ososo-aburo	
	Local composite	Bida 6	
	Akoka	Badagry 1	
	Bende white	Idomi	
	Agwu 2	Aburo	
	Ogbomosho		
	Abrupa 4		

Source: Makanjuola and Odebiyi (1990).

Thus, our result has shown that husk quality is only useful in reducing the level of *S. zeamais* infestation (Table 7) when the ear is protected from other ear infesting insects which may predispose it to these field to store pests. Generally, the improved varieties were characterized by poor husk quality and only 3 out of the 17 improved ones were found to possess good grain quality. Eight out of best 10 resistant varieties were local ones which were also resistant in the laboratory. Although these local varieties have small cobs and generally low yield, they possess good resistant traits that we recommend can be used in pest management breeding programmes.

Table 7. Correlation coefficients of husk quality and field infestation parameters

	Husk Quality Rating
Initial population	-0.407***
Population 50 days after harvest	-0.555***
Rate of emergence	0.124 NS
Number of Grain damaged	-0.591***
Weight of Grain damaged	-0.632***
Grain weight loss due to *S. zeamais*	-0.597***

****Significant at P = 0.0001*
Source: Makanjuola and Odebiyi (1990)

Screening Maize Varieties under CRIB Storage Conditions

Our study went on further to screen 77 varieties in open fields surrounded by old maize fields similar to the practices of the peasant farmers. At 50 days of storage, the mean number of weevils per 50g sample varied from 10.75 to 113 while percentage grain damage ranged from 8.5 to 51.9% with a resultant weight loss ranging from 0.12 to 18.2%. Out of the 77 varieties, seven were considered relatively resistant, 40 moderately susceptible, 16 susceptible and 14 highly susceptible after 5 weeks. However, with increase in storage period to 5 months, although weevil population ranged from 17.3 to 91.0, it did not appear to have significantly increased although there was a significant increase in percentage grain damage ranging from 34.03 to 84.35% resulting in corresponding weight loss of 8.18 to 36.69%. Generally between the 50 days and 5 months storage period the level of damage increased by 70 fold in the resistant variety (Umunachi) and 2 fold in the most susceptible variety. We were able to show that without any other protection measure, there was break down in resistance. This goes to show that resistance alone is not adequate for grain storage. There is need for an integrated management of the grains in storage using other suitable control tactics.

Further work was carried out to identify the characteristics in the grain responsible for this resistance. Our findings showed that starch content influenced the number of weevils that emerged as well as the developmental period. It was noted that sugar may prolong development period, reduce the number of emerging adults and subsequently increase resistant. Grain hardness had no role to play in conferring resistance as far as this study was concerned; while most reports from other research related hardness as being responsible for resistance. However this results agree with the suggestion by Painter (1951) that tissue hardness in varieties cannot be large enough to affect the degree of feeding of an insect accustomed to the

host species. The differences obtained by other workers might be due to other attractive differences of the surfaces which impact tissue hardness. The reported observation in the publication initiated a number of breeders / plant geneticists who were interested especially in the local maize varieties.

Cowpea versus *Maruca testulalis*

Following my research on resistance in maize, I carried out a more intriguing one on cowpea. This was a Ph.D research supervised by me at the University of Lagos using part of the facilities at IITA. I must say at this point that the research attracted a fellowship for my Ph.D student, Sunday Oghiakhe, at IITA. Our main interest was to search for cowpea varieties that will withstand the pressure of *Maruca testulalis* (Plates 13-15) in the field during cowpea production.

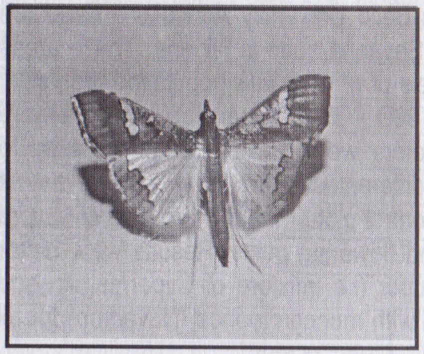

Plate 13. *Maruca testulalis adult*

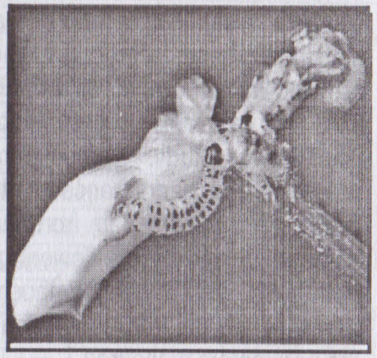

Plate 14. Larvae of *Maruca testulalis (vitrata).*

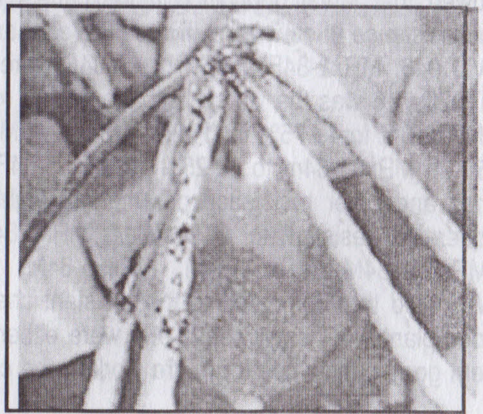

Plate 15. *Damaged pods of cowpea by Maruca testulalis*

The research is significant because not only do insect pests constitute the greatest problem in cowpea production, but of all cowpea pests *Maruca testulalis* is the most economically important one. It feeds on every part of the cowpea plant and has been reported to account for as high as 80% reduction in grain yield in Nigeria (IITA, 1984). A lot of research had been carried out in Africa to obtain a resistant variety to *M. testulalis*. We therefore wanted to identify cowpea lines that have some degree of resistance to *M. testulalis* so that we can reduce the amount of insecticide in use during crop cultivation. We were set to identify breeding lines that showed levels of resistance to *M. testulalis* for use either directly or as a parent in cowpea breeding program. The study was carried out using 115 cowpea cultivars developed for resistance to the pod borer and two insecticide protection regimes namely Nuvacron and Cymbush Super ED at IITA. The work was carried out at an IITA farm located in a transitional zone of humid rain forest of South West Nigeria and Ahmadu Bello University Agriculture Research station in Mokwa located in Guinea Savanna zone in Nigeria. These areas are well known for their different levels of *M. testulalis* population presence; TVU 946; a resistant check; and IT82D – 716; a susceptible check were used in this study. Various parameters were taken during the study to determine the performance of the different cultivars. It was however not possible to take any data from the control plot at Ibadan because of severe damage caused by pre-flowering and flowering pests. Results were better from plots treated with Cymbush Super (i.e. mixture of Cypermethrin and dimethoate) than from those treated with monocrotophos (Nuvacron) for all the parameters measured.

Our results showed that larval population alone cannot be used in the categorization of resistance of cowpea cultivars (Tables 8 and 9). In Ibadan and Mokwa, TVU 946, MRx2-84F and MRx109-84F were the best three cultivars while IT82D-716 was the worst. In Ibadan, yield reduction ranged from 3.47% in MRx2-84t to 49.75% in IT82D-716 and in Mokwa the range was from 10.65% in MRx34-84m to 52.25% in MRx15-84F. Based on the yield performance and other resistance parameters, eight cultivars were selected as moderately resistant to *M. testulalis* MRx2-84F, MRx4784M, MRx50-84M, MRx109-84M, MRx54-84M, MRx55-84M, MRx8-84F and MRx48-84M. We noted that compared to the resistant check TVU946 the cultivars had good plant type, small seeds and were either white or brown thus making them good candidates for future work in the cowpea breeding program.

Table 8. Grain yield from 18 cowpea cultivars grown under two insecticide protection regimes. *Ibadan, second season, 1986

Cultivar	Yield (kg ha^{-1})		% Yield loss due to *M. testulalis**
	Nuvacron (A)	Cymbush Super ED (B)	
TVu 946 (RC)	713.0a	931.0abc	23.41fg
MRx2-84F	636.5ab	662.5h	3.47i
MRx109-84M	613.0ab	753.0fgh	18.59g
MRx15-84F	574.0ab	875.0cde	34.40cd
MRx5-84F	518.5b	875.5bcdef	39.50bc
MRx6-84F	621.5ab	854.5bcdef	27.27ef
MRx42-84M	505.5b	775.5efg	34.82cd
MRx54-84M	577.5ab	779.0efg	25.87ef
MRx8-84F	549.5ab	950.5ab	42.19b
MRx56-84M	533.0b	902.0bcd	40.91bc
MRx48-84M	611.5ab	826.5cdefg	26.01ef
MRx49-84M	638.0ab	725.0gh	12.00h
MRx50-84M	612.5ab	816.0dfg	24.94ef
MRx53-84M	606.5ab	863.0bcde	29.72de
MRx57-84M	579.0ab	903.0bcd	35.88c
MRx47-84M	510.0b	777.5efg	34.41cd
MRx55-84M	533.0b	752.0fgh	29.12def
IT82D-716 (SC)	506.0b	1007.0a	49.75a
Mean	580.08a	833.89b	2959

**Unprotected plots had no recorded yield due to severe thrips infestation*

Means in a column followed by a common letter are not significantly different at 5% level (DMRT) $\frac{(B-A)}{(B)} \times 100$

Source: Oghiakhe *et al.* (1995).

Table 9. Grain yield from 18 cowpea cultivars grown under two insecticide protection regimes *Mokwa, main season, 1986

Cultivar	Yield (kg ha^{-1})		% Yield loss due to *M. testulalis**
	Nuvacron (A)	Cymbush Super ED (B)	
TVu 946 (RC)	1228.88i	1537.76fg	20.08f
MRx2-84F	1563.32cde	2296.65ab	31.93cd
MRx109-84M	1013.33j	1531.10fg	33.82c
MRx15-84F	665.55k	1393.32g	52.23a
MRx5-84F	16.24.43abcd	2113.31bc	27.87cde
MRx6-84F	1737.76a	2605.53a	33.30c
MRx42-84M	1371.10h	1688.87defg	18.82f
MRx54-84M	1649.99abc	1846.65cdef	1065h
MRx8-84F	1599.99abc	1913.32cdef	16.38fgh
MRx56-84M	1433.32efgh	1792.20cdef	20.02f
MRx48-84M	1465.54efgh	1779.98cdef	17.67fg
MRx49-84M	1724.43ab	2137.76bc	19.33f
MRx50-84M	1531.10cdef	1966.65cde	22.15ef
MRx53-84M	1513.32defg	1903.32cdef	20.49f
MRx57-84M	1196.66i	1986.65bcd	39.76b
MRx47-84M	1422.21fgh	1942.20bcde	26.77de
MRx55-84M	1391.10gh	1579.99efg	11.96gh
IT82D-716 (SC)	1048.00j	1847.76cdef	43.28b

**In all cases the unprotected plots yielded zero, except for the resistant check (TVu 946) which yielded 388.89kg ha^{-1} Means in a column followed by a common letter are not significantly different at 5% level (DMRT).*
Source: Oghiakhe et al. (1995).

Rapid Visual Screening Technique for Cowpea Resistance to *Maruca testulalis*

In continuity of our work while we were able to identify cowpea varieties with some measure of resistant to *Maruca testulalis.* We were also able to develop a rapid visual field screening technique for resistance of cowpea to the legume pod borer. This is because the earlier method of screening cowpea resistance, as developed by Jackai (1982) and initially used in our study, was found to be cumbersome and also involved the use of many damage parameters both in the field and the laboratory. We developed this new method as an improved technique which is less cumbersome, rapid and accurate.

This rapid visual technique for flowers and/or pod evaluation index involved measuring two damage parameters. First was the field examination of pods for signs of injury or larval presence. We thereafter calculated the ratio of pod load to pod damage i.e. the rapid visual technique for pods. The result obtained was a highly significant (P<0.01) correlation between the rapid visual field screening technique and the existing field screening one, thus indicating that this new technique is a reliable indicator of the former (Tables 10-13). Consistency and repeatability were demonstrated using the rapid technique across locations and seasons. This method has since been adopted for its simplicity and time saving trait.

We used this new technique (RVT) going a step further to study the influence of various factors on resistance of the cowpea crop.

Table 10. Correlations between the rapid visual technique for flowers (RVT-flowers) and damage variables used in screening for cowpea resistance to *Maruca testulalis* in 1985.

	Larvae/25 flowers	Pod evaluation index	Plant resistance index
RVT (flowers) Ibadan[1]	0.64**	-0.33**	0.87**
RVT (flowers) Ibadan[2]	0.40**	-0/71*	0.54**
RVT (flowers) Mokwa	0.56**	-0.56**	0.40**

*n=72**=Significant at P<0.01. [1]First season; [2]Second season.*
Source: Oghiakhe et al. (1992).

Table 11. Correlations between the pod evaluation index (Ipe) and damage variables used in screening for cowpea resistance to *Maruca testulalis* in 1985.

	Larvae/25 flowers	Plant resistance index
Ipe Ibadan[1]	-0.45**	-0.61**
Ipe Ibadan[2]	-0.43**	-0.72**
Ipe Mokwa	-0.50**	-0.28*

*n=72 * and ** Significant at (P<0.05) and (<0.01) respectively; [1]First season; [2]Second season.*
Source: Oghiakhe et al. (1992).

Table 12. Correlation matrix between rapid visual technique for flowers across locations and seasons in 1985

	RVT (flowers) Ibadan[1]	RVT (flowers) Mokwa
RVT (flowers) Ibadan[1]	0.58**	0.62**
RVT (flowers) Mokwa	0.51**	

*n=72**Significant at P<0.01. [1]First season; [2]Second season.*
Source: Oghiakhe et al. (1992).

Table 13. Correlation matrix between rapid visual technique for pods across locations and seasons in 1985

	RVT (flowers) Ibadan[1]	RVT (flowers) Mokwa
Ipe Ibadan[1]	0.54**	0.50**
Ipe Mokwa	0.36**	

*n=72**Significant at P<0.01. [1]First season; [2]Second season.*
Source: Oghiakhe et al. (1992).

A. PLANT ARCHITECTURE IN RESISTANCE

My research team noticed that several types of plant architecture do exist for cowpea. With the knowledge that plant architecture not only confers resistance to insects but improves yield and quality of produce (Coyne 1980), we decided to investigate their role in resistance to *Maruca testulalis*. In the cowpea crop most insects live on or within plant hosts which not only provide food but also shelter and essential micro-habitat. In this study, we therefore decided to look at leaf canopy structure and the position of the fruiting structure in order to answer two questions-

- **Does *M. testulalis* prefer the open or dense leaf canopy structure?**
- **Does *M. testulalis* prefer pods that are placed within or above canopy?**

Various opinions, based on speculations by researchers exist since most works have been focused on antibiosis, antixenosis and tolerance. However as knowledge is limited on the effect of canopy structure and pod position on cowpea resistance to *M. testulalis*, we therefore investigated its effect on the insect as regards damage. Our findings showed that pods held within the canopy suffered significantly more damage (P<0.05) than cultivars with pods held in normal position. Also defoliated cultivars, i.e. less dense canopy sustained, significantly lesser infestation and damage (P<0.05) than undefoliated (denser) cultivars. Our findings showed that relative humidity

was lower in defoliated cultivars while soil and ambient temperature were higher thereby making it less favorable for *M. testulalis*. Percentage pod damage and larval infestation by *M. testulalis* in flowers were positively correlated with relative humidity and negatively correlated with temperature, with both correlation being significant (P<0.01). We therefore recommend that breeders should select and breed for cultivars with less dense foliage (open canopy and long peduncle holding the reproductive structures above the canopy which may likely increase resistance to *M. testulalis* (Tables 14 and 15; Figures 7 - 10).

Table 14. Cowpea structure in relation to damage caused by *Maruca testulalis* in two cultivars: TVu 946 and IT82D-716

Cowpea cultivar	No. of larvae/30 flowers*	Percentage flower infestation*	Larval parasitization *	Percentage pod damage	Seed damage index
TVu 946 (defoliated)	5.75 + 1.75 a	10.00 + 1.36 b	3.75 + 0.63 b	18.34 + 4.41 b	63.33 + 4.30 a
TVu 946 (undefoliated)	7.25 + 1.11 a	38.33 + 2.15 a	10.25 + 0.85 a	30.83 + 2.85 a	81.67 + 9.95 a
IT82D-716 (defoliated)	29.25 + 1.80 d	62.50 + 4.98 d	25.50 + 0.65 d	56.67 + 6.60 d	250.67 + 23.62 c
IT82D-716 (undefoliated)	45.5 + 2.75 c	93.33 + 4.71 c	35.50 + 1.89 c	88.34 + 2.88 c	380.00 + 43.80 b
CV%	10.63	16.09	6.84	15.36	20.21
S.E.	0.25	3.79	0.14	3.73	19.60

**Analysis is based on values transformed to $\sqrt{x + 0.5}$.*
**Analysis is based on values transformed to aresin $\sqrt{x/100}$*
Mean + S.E. in each vertical column followed by the same letter are not significantly different at 5% level (DMRT)
Source: Oghiakhe et al. (1991).

Table 15. Micrometereological measurements with respect to cowpea canopy structure in two cultivars: TVu 946 and IT82D-716

Microclimate	TVu 946 (undefoliated) λ ± S.E.	TVu 946 (defoliated) λ ± S.E.	IT82D-716 (undefoliated) λ ± S.E.	IT82D-716 (defoliated) λ ± S.E.
R.h (daily max) %	97.50 ± 1.50	81.00 ± 2.31	91.67 ± 2.33	85.00 ± 1.63
R.h (daily min) %	76.00 ± 1.00	43.33 ± 6.70	63.00 ± 5.24	46.00 ± 5.13
temp. (daily max) °C	30.00 ± 0.50	36.50 ± 1.04	34.33 ± 0.83	35.00 ± 0.15
Temp. (daily min) °C	24.75 ± 0.25	27.50 ± 0.00	24.66 ± 0.93	25.75 ± 0.25
Soil temp. (5cm depth) max	28.25 ± 0.25	33.50 ± 0.50	29.83 ± 0.17	34.60 ±0.50
Soil temp. (5 cm depth) min	25.25 ± 0.25	27.83 ± 0.17	24.63 ± 0.17	28.00 ± 0.28

Source: Oghiakhe et. al. (1991).

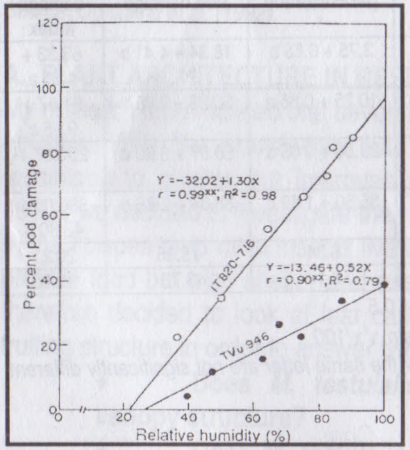

Figure 7. Relationship between relative humidity measured under leaf canopy and percentage pod damage by M. testulalis larvae in cowpea cultivars TVu 946 and IT82D-716
Source: Oghiakhe et al. (1991).

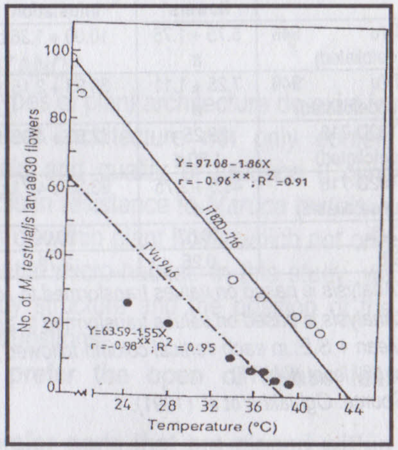

Figure 8. Relationship between temperature measured under leaf canopy and number of M. testulalis larvae/30 flowers in cowpea cultivars TVu 946 and IT82D-716.
Source: Oghiakhe et al. (1991).

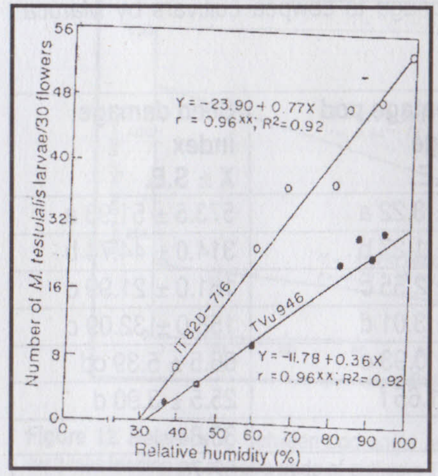

Figure 9. Relationship between relative humidity measured under leaf canopy and number of M. testulalis larvae/30 flowers in cowpea cultivars TVu 946 and IT82D-716.
Source: Oghiakhe et al. (1991).

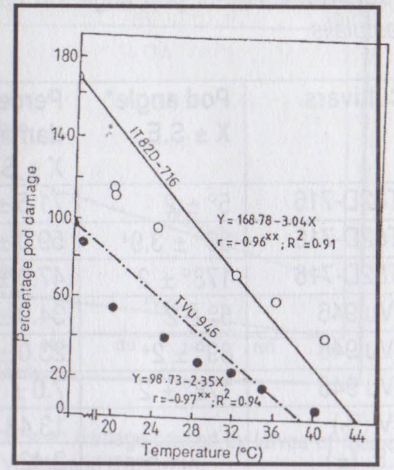

Figure 10. Relationship between temperature measured under leaf canopy and percentage damage by M. testulalis larvae in cowpea cultivars TVu 946 and IT82-716.
Source: Oghiakhe et al. (1991).

B. POD ANGLE IN RELATION TO RESISTANCE

Another architectural character we investigated in relation to *Maruca testulalis* infestation and damage was the effect of pod angle. A resistant variety TVu 946 and a susceptible variety IT82-716 were used for the study. Three pod angles were used in the study. Our findings showed a negative and highly significant ($P<0.01$) relationships between the pod angle and percentage pod damage as well as the seed damage index in the two cultivars. Pods with wide angles were damaged on mostly one and rarely two pods. Our recommendation Mr. Vice-Chancellor Sir, to our collaborators, the plant breeder and geneticist is that they should breed for wide pod angle to help reduce the damage of this all important economic pest *M. testulalis* to the cowpea pod (Table 16; Figures 11 and 12).

Table 16. Effect of pod angle on damage to cowpea cultivars by *Maruca testulalis*

Cultivars	Pod angle* X ± S.E.	Percentage pod damage X ± S.E.	Seed damage index X ± S.E.
IT82D-716	5° ± 2	71.5 ± 3.22 a	573.5 ± 51.98 a
IT82D-716	39° ± 3.9+	59.0 ± 1.27 b	314.0 ± 44.74 b
IT82D-716	178° ± 2	47.0 ± 2.55 c	161.0 ± 21.99 c
TVu 946	5° ± 2	34.0 ± 3.01 d	158.0 ± 32.09 c
TVu 946	89° ± 2+	23.0 ± 0.93 e	66.5 ± 5.39 cd
TVu 946	178° ± 2	7.0 ± 1.65 f	25.5 ± 3.90 d
CV (%)		13.43	33.84
S.E. (±)		2.42	32.75

Means in each column followed by the same letter are not significantly different at 5% level (DMRT).
**Average of 15 measurements.*
+Normal pod angle
Source: Oghiakhe et al. (1992).

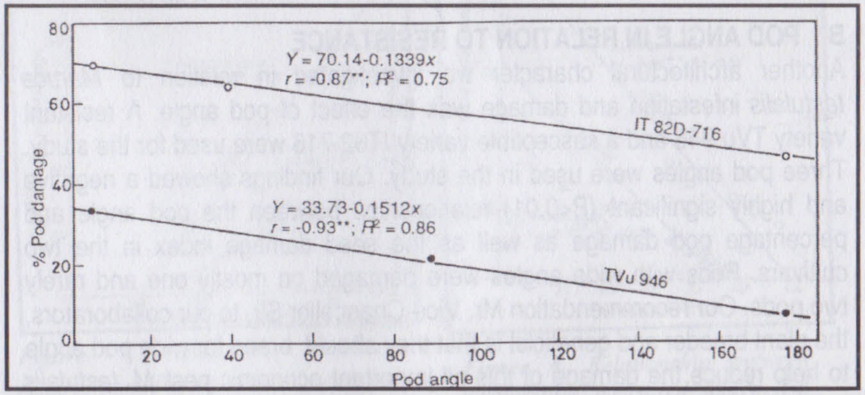

Figure 11. Relationship between pod angle and pod damage percentage caused by larvae of Maruca testulalis feeding on cowpea pods of cultivars TVu 946 and IT82-716. Source: Oghiakhe et al. (1992).

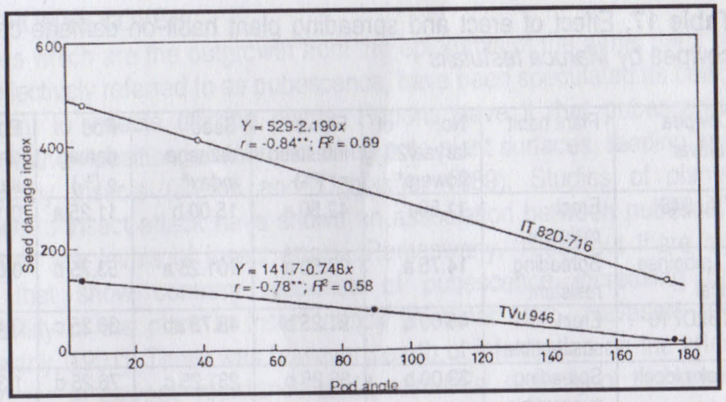

Figure 12. Relationship between pod angle and seed damage caused by larvae of *Maruca testulalis* feeding on cowpea pods of cultivars TVu 946 and IT82D-716. Source: Oghiakhe *et al.* (1992).

C. PLANT GROWTH HABIT

We also looked at the effect of plant growth habit in relation to infestation and damage by *M. tetulalis*. Using five cowpea cultivars of known agronomic and architectural characteristics in this study. Our findings showed that seed and pod damage assessment values were better in profuse flowering than in non-profuse flowering cultivars and in erect cultivars than in spreading cultivars. Best performances were obtained from TVu 946 (profuse and erect resistant) and worst in Oloka local (spreading and susceptible) and vita 3 (susceptible and non profuse) respectively (Tables 17 and 18). Mr. Vice-Chancellor Sir, we thereby propose that breeders should incorporate plant growth habits into cowpea cultivars because they are good architectural components for reducing *M. testulalis*'s damage to cowpea.

Table 17. Effect of erect and spreading plant habit on damage caused to cowpea by *Maruca testulalis*

Cowpea cultivar	Plant habit	No. of larvae/20 flowers*	Flower infestation$^+$ (%)	Seed damage index≠	Pod damage (%)	Pod damage severity
TVu 946	Erect resistant	11.50a**	42.50 a	15.00 b	11.25 a	0.14 a
Kamboinse local	Spreading resistant	14.75 a	27.50 a	101.25 a	53.75 b	0.80 b
IT82D716	Erect susceptible	45.00 b	91.25 b	48.75 ab	36.25 c	0.43 c
Oloka local	Spreading susceptible	33.00 b	86.25 b	231.25 c	76.25 d	1.34 d
	CV%	18.25	24.65	41.23	22.61	25.15
	SE ±	0.29	7.02	7.22	8.42	0.14

*Values transformed to $\sqrt{x + 0.05}$ before analysis
$^+$Values transformed to arcsine $\sqrt{x/100}$ before analysis
≠Higher values indicate greater seed damage.
**Means in each column followed by the same letter are not significantly different at 5% level (Duncan's multiple range test). Average of four replicates.
Source: Oghiakhe *et al.* (1993).

Table 18. Effect of flower frequency on damage caused to cowpea by *Maruca testulalis*

Cowpea cultivar	**Plant habit**	**No. of larvae/20 flowers***	**Flower infestation$^+$ (%)**	**Seed damage index≠**	**Pod damage (%)**	**Pod damage severity**
TVu 946	Resistant profuse	24.50 a**	40.00 a	11.25 a	6.25 a	0.08 a
Kamboinse local	Resistant non-profuse	22.00 a	33.75 a	78.75 b	41.25 a	0.51 a
IT82D716	Susceptible profuse	37.25 b	82.50 b	55.00 c	31.25 ab	0.41 a
VITA-3	Susceptible non-profuse	77.25 c	81.25 b	143.75 d	85.00 c	1.11 b
	CV%	9.58	27.13	20.00	41.13	53.82
	SE ±	0.29	7.02	7.22	8.42	0.14

*Values transformed to $\sqrt{x + 0.05}$ before analysis
$^+$Values transformed to arcsine $\sqrt{x/100}$ before analysis
≠Higher values indicate greater seed damage.
**Means in each column followed by the same letter are not significantly different at 5% level (Duncan's multiple range test). Average of four replicates.
Source: Oghiakhe *et al.* (1993).

D. TRICHOMES COVER

Trichomes which are the outgrowth from the epidermis of the aerial parts of plant, collectively referred to as pubescence, have been speculated as being a deterrent to insects utilizing plants. Reports have it that pubescence interfere with oviposition, attachment of eggs to plant surfaces, feeding and ingestion by insects (Jackai and Oghiakhe, 1989). Studies of plants' resistance to insect attack have shown an association between pubescent leaves and low levels of insect attack (Ramaswany, 1988) but there are studies that show contrary response of pubescence increasing the susceptibility of the plant to insect attack (Webstar 1975, Navasero and Ramaswany, 1991). There was however dearth of information on the effect of trichomes in cowpea resistance to *M. testulalis.* A study of trichome's morphology, orientation and distribution on resistant and susceptible cultivars of cowpea stem, leaves and pods to determine if there was any association between trichome and the damage by *M. testulalis* was undertaken.

Our studies revealed that trichome's cover on individual cultivars varied between different plant parts in its length and density but not in its type (Figure 13). Trichome density on different parts decreased with increasing plant age. There was significant ($P<0.05$) negative correlation between total trichome density on pods, pod infestation and damage severity but there was no relationship between the length of non-glandulous trichomes on pod, pod infestation and damage severity. We concluded that trichome density is important in reducing damage to cultivated cowpea by larvae of *M. testulalis.* Efforts should be intensified for higher level of trichomes in high yielding desirable cowpea cultivars to be incorporated in breeding programme. This will be an important component in integrated management of *M. testulalis.*

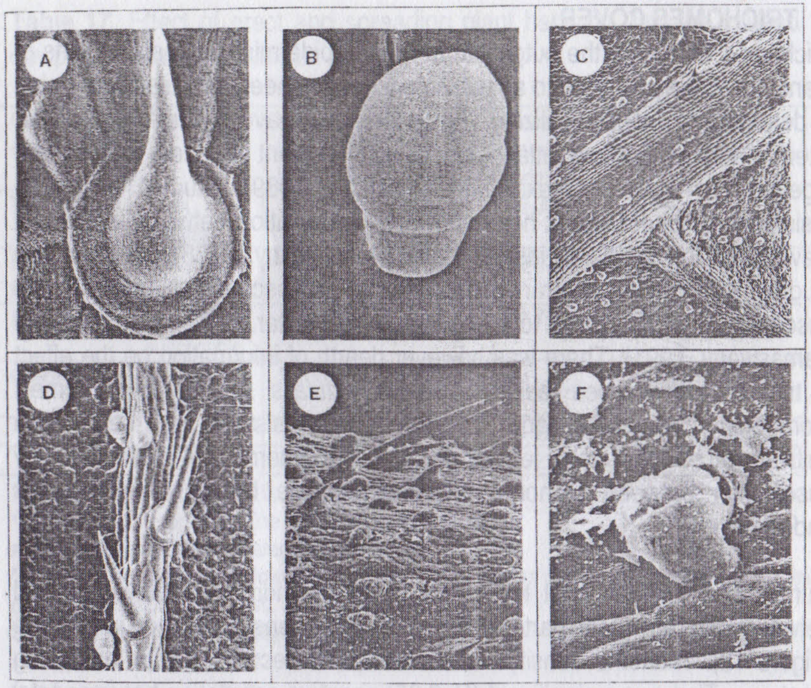

Figure 13. Scanning electron micrograph of **(A)** non-glandular trichome on TVu 946; **(B)** glandular trichome on TVu 946; **(C)** the abaxial leaf surface of MRx2-84F showing distribution of glandular and non-glandular trichomes; **(D)** glandular and non-glandular trichomes on primary vein of adaxial leaf surface of TVu 946; **(E)** glandular and non-glandular trichomes on mature pod wall of TVu 946; **(F)** stem surface of MRx2-84F with glandular trichome.
Source: Oghiakhe *et al.* (1992).

Table 19. Pod infestation and damage severity measurements taken on three cowpea cultivars under field conditions.

Cultivar	Percentage pod infestations			Severity of pod damage		
	Ibadan first season	Ibadan second season	Mokwa main season	Ibadan first season	Ibadan second season	Mokwa main season
MRx109-84M	20.0bc	8.0c	23.0b	0.24bc	0.09b	0.27b
TVu 946	18.0bc	13.0c	24.0b	0.19c	0.14b	0.27b
IT82D-716	55.0a	49.0a	100.0a	0.95a	0.95a	3.37a

Means in each column followed by the same letter(s) are not significantly different at the 5% level by Duncan's (1955) Multiple Range Test. Values are means of 4 replicates.
Source: Oghiakhe *et al.* (1992).

Table 20. Regression equations and correlation coefficients relating total trichome density on pods (X) to pod damage (Y) on cowpea.

Trichome type	Damage parameter	Cropping season and location	Regression equation	
Glandular and non-glandular trichome	Pod infestation	1985FS[1] (Ibadan)	Y = 48.97-0.09X	-0.81**
		1985SS[2] (Ibadan	Y = 38.97-0.08X	-0.67*
		1985MS[3] (Mokwa)	Y = 98.65-0.23X	-0.95**
Glandular and non-glandular trichome	Pod severity	1985FS (Ibadan)	Y = 0.78-1.89X	-0.73**
		1985SS (Ibadan)	Y = 0.58-0.001X	-0.67*
		1985MS (Mokwa)	Y = 2.81-0.008X	-0.78**

Source: Oghiakhe et al. (1992).

E. ANATOMICAL FEATURES

We investigated the anatomical features of the stem and pod wall have any role to play in the resistant of cowpea to *M. testulalis*. The study revealed that there were significant varietal differences (P<0.05) in the distance between epidermis and collenchyma cells of the slightly raised (convex) and concave portions of TVu 946 and IT82D-716 stems (Table 21). The convex portion of TVu 946 stem showed more compact collenchymas cells than IT82D-716 and vice versa for the concave portion. TVu 946 had a smaller stem diameter than IT82D-716 but the difference was not significant. Distance between epicarp and mesocarp tissues of 7-day old TVu 946 and IT82D-716 pod wall did not show any significant difference (Table 22). If the trends obtained in this study are typical of a cultivated cowpea, pod wall anatomy will appear to be of little or no disadvantage to boring larvae. Similarly the cell and tissue arrangement and the absence of strengthening tissues in pod wall (Figures 14 and 15) could probably have some of the most important constraints responsible for their vulnerability to larval damage.

We therefore concluded that stem anatomy is an important factor in stem resistance to *M. testulalis*. Nevertheless, this does not appear to be so in the case of pod wall resistance.

Table 21. Mean distance* between epidermis and collenchymas cells of cowpea stems

Cultivar	Cross section (mm ± S.E.)	
	Convex portion	Concave portion
TVu 946	0.267 ± 0.016 a	0.209 ± 0.005 a
IT82D-716	0.345 ± 0.015 b	0.193 ± 0.008 b

*Average of 10 measurements taken from three cross sections
*Means followed by the same letter in each column are not significantly different at $P < 0.05$ according to Duncan's multiple range test.
Source: Oghiakhe *et al.* (1991).

Table 22. Mean distance* between epicarp tissue of cowpea pod wall

Cultivar	Distance between epicarp and mesocarp tissue (mm ± S.E.)
TVu 946	0.253 ± 0.003 a+
IT82D-716	0.241 ± 0.005 a

*Average of 10 measurements taken from three cross sections
*Means followed by the same letter are not significantly different at <0.05 according to Duncan's multiple range test.
Source: Oghiakhe *et al.* (1991).

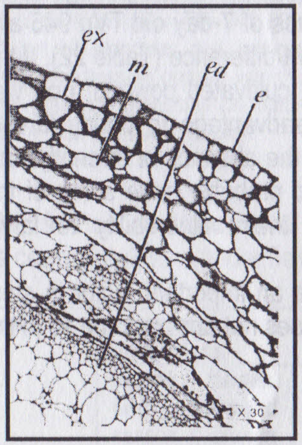

Figure 14. Transverse section through pod wall of cowpea cv.TVu 946 showing epicarp (e), exocarp (ex), mesocarp (m) and endocarp (ed).
Source: Oghiakhe *et al.* (1991).

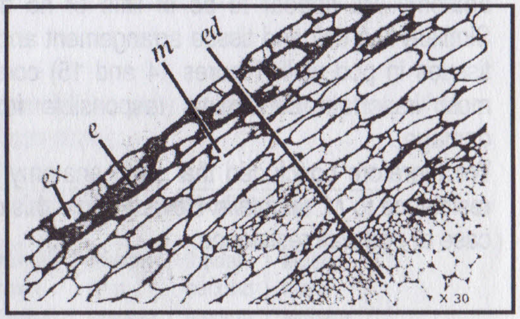

Figure 15. Transverse section through pod wall of cowpea cv.IT82D-716 showing epicarp (e), exocarp (ex), mesocarp (m) and endocarp (ed).
Source: Oghiakhe *et al.* (1991).

F. PHENOL CONCENTRATION

Different phenol concentrations present in plants play important defensive roles against insects. From the wide range of cowpea cultivars screened for resistance to *Maruca testulalis*, low levels of antibiosis have been found in semi-wild and wild species (Oghiakhe *et al.*, 1993). Hence, it was of interest to us to investigate if there was any link between the concentration of phenol in cowpea and the field resistance of *M. testulalis* due to the dearth of information on phenol involvement in antibiosis to *M. testulalis*. From our study, we were able to show that phenol concentration varied significantly ($P < 0.05$) among different parts of the cultivars at the same growth stage and generally decreased with increase plant age (Table 23). Despite these differences the correlation showed that phenol does not play any significant role in cowpea resistance to *M. testulalis* (Table 24).

Table 23. Phenolic content (mg/mg ± S.E.) in different parts of cowpea cultivars

Cultivar	Fresh seed	Dry seed	Fresh pod wall	Dry pod wall	Seed coat	Cotyledon
IT82D-716 (susceptible)	0.244 ± 0.02a	0.155 ± 0.02c	0.285 ± 0.2a	0.217 ± 0.01c	0.676 ± 0.02a	0.038 ± 0.01c
TVu 946 (resistant)	0.518 ± 0.03b	0.180 ± 0.01d	0.364 ± 0.01b	0.255 ± 0.05d	0.873 ± 0.04b	0.030 ± 0.01d

Means in each column followed by the same letter are not significantly different at $P = 0.05$ (Duncan's multiple range test). Values are means of six replicates.
Comparison between fresh and dry seed, fresh and dry pod wall, seed coat and cotyledon only.
Source: Oghiakhe *et al.* (1993).

Table 24. Correlations between phenol concentration in cowpea cultivars and resistance parameters measured under field conditions in 1985.

Resistance parameter	Phenol concentration		
	Ibadan First season	Ibadan Second season	Mokwa Main season
Pod damage	-0.55	-0.47	-0.43
Flower infestation	0.33	0.06	0.20
Larvae per 25 flowers	0.30	0.08	0.13

Source: Oghiakhe *et al.* (1993).

In summary, our studies showed that cowpea contains very low level of allelochemicals which have no practical significance in preventing damage by *M. testulalis*. We therefore recommended the selection and breeding of cowpea cultivars with moderate level of phenols. Morphological and biophysical forms of resistance were also recommended for incorporation by breeders to improve the overall level of cowpea resistance to *M. testulalis*.

GRAIN STORAGE MANAGEMENT

There are challenges posed by insect pests in storage thereby creating problems for the agro industry who purchase large quantity of grains when they are cheap. There might be a need to proffer solutions to storage problems emerging in grain storage.

While we were screening some maize varieties for resistance at IITA, all the insect pests on a particular variety, which had been stored for over 18 months died even though this variety had no history of insecticidal treatment. The screening was repeated several times with the same results. We thought it was a case of complete resistance. However on investigation, we were told that the maize had been contaminated with insecticide along the line. There and then, we considered the challenges that accompany the use of insecticides, there must be an alternative method of incorporating stored product's resistance to pests that is not deleterious to man and the ecosystem. Apart from the previously stated insecticide challenges, my students at the undergraduate and Masters' level had already established an additional challenge. They discovered that insecticides recommended dosages as stated by their manufacturers are often well above that which is actually needed to give effective control probably due to the fact that trials are usually carried out in temperate regions where they are manufactured. This manufacturer recommended dosage, will not only enhance the rapid development of resistance, it will also endanger non-target organisms. In order to prove the existence of this new challenge, we carried out several trials on the efficacy of actellic, sumithion and other organophosphates under ambient conditions. From the trials, we discovered half the recommended dose gave as good a control as the manufacturer's recommended dose for a three months post-treatment period. According to our findings, the reason for this disparity can be attributed to the difference in the manufacturer's and our own ambient conditions. With differing ambient conditions, there was always bound to be a difference in trial conditions and subsequently a difference in the recommended dosages. We therefore recommended that every insecticide must be tested under the ambient condition of the country where it is used.

Now due to the residue problems often encountered during storage, a possible solution to this challenge is to adopt botanicals as protectants of grains and pulses in storage. I explored carrying out a survey on plants and identifying suitable ones for evaluation. This was followed up by my Ph.D students beginning with Agunama, Leo who worked on neem, and others, Dr. A.A. Denloye and Negbenebor, Helen, whom all carried out survey in various parts of the country. From the various surveys we were able to locate and identify suitable plants for evaluation, some of them already in use and others known to be medicinal plants for control of some parasites/pathogen but not known for their insecticidal property.

After identifying the plants to be researched on, using various formulations of the botanical *Chenopodium ambrosioides*, on three stored product pests we came up with the following findings. The powder formulation of the plant was most potent on *S. zeamais* when compared to *C. maculatus* and *T. castaneum* with LC_{50} value of 0.46g/kg, 1.60g/kg and 2/14g/kg respectively. The ethanol extract was however most toxic to *C. maculatus* with a 48h LC_{50} of 0.023g/l (Tables 25 and 26) (Denloye *et. al.* 2010). Within 24 hour exposure significant kill was obtained at low concentration in the bioassay carried out. The eggs of *C. maculatus* were significantly affected, but the oil extract did not cause any appreciable larval mortality. Generally, *C. ambrosicoides* powder protected grains from significant damage and weight loss for 5 months under field conditions. Our results indicate that *C. ambrosicoides* is an oviposition suppressant and ovicide which has potentials for grain protection. We therefore recommend that farmers use this plant to protect stored cowpea in small storage system. The oil extract acted as a fumigant on the eggs and adults of *C. maculatus* and *S. zeamais* adult. However, it was not active on the larvae (Table 27).

Table 25. Toxicity of *C. ambrosioides* powder and extracts against test insect species

Formulation	Test insect species	48 h LC_{50}	95% confidence limits	Regression equation	DF	Slope [±SE]
Powder	*C. maculatus*	0.050 [g/kg]	0.01–0.23	Y = 2.77+2.12 x	4	2.12±0.75
	S. zeamais	0.49 [g/kg]	0.17–1.20	Y = 0.33+1.04 x	4	1.04±0.03
	T. castaneum	2.57 [g/kg]	1.80–3.58	Y = –0.52+1.25 x	4	1.25±0.02
Aqueous	*C. maculatus*	1.21 [g/l]	0.93–1.52	Y = –0.11+1.36 x	3	1.36±0.03
	S. zeamais	2.43 [g/l]	1.09–3.18	Y = – 0.46+1.19 x	3	1.19±0.03
	T. castaneum	2.14 [g/l]	1.67–2.77	Y = 0.84+1.17 x	3	1.19±0.03
Ethanol	*C. maculatus*	0.02 [g/l]	0.02–0.03	Y = 2.84+1.73 x	3	1.73±0.04
	S. zeamais	0.04 [g/l]	0.03–0.06	Y = 1.99+1.46 x	3	1.46±0.02
	T. castaneum	0.04 [g/l]	0.03–0.06	Y = 1.99+1.46 x	3	1.17±0.02

DF – degree of freedom ; SE – standard error LC_{50} values of with no overlap in their 95% confidence limits are not significantly different ($p < 0.05$)
Source: Denloye *et. al.* (2010).

Table 26. Effects of *C. ambrosioides* ethanol extract on oviposition and progeny production of *C. maculatus*

Treatment [g/l]	Mean number of eggs laid [±SE]	Mean adult emergence [±SE]	Mean percent adult emergence [±SE]
[0.00]	96.00±10.10 a	40.00±2.16	42.20±6.99
[0.025]	70.00±2.58 b	28.00±4.32	39.94±5.33
[0.10]	21.00±2.45 c	8.00±1.83	39.13±12.68

Column means bearing same superscripts are not significantly different ($p > 0.05$) by Least Significant Difference (LSD) test
SE – standard error
Source: Denloye *et. al.* (2010).

Table 27. Fumigant toxicity of *C. ambrosioides* essential oil to adult, egg, and larval test insect species

Test insect species		24 h LC_{50} [µl/l]	95% confidence limits	Regression equation	DF	Slope [±SE]
C. maculatus	adult	1.33	1.13–1.56	Y = –0.26+2.08 x	3	2.078±0.04
	egg	2.07	1.64–2.56	Y = –0.79+2.50 x	3	2.50±0.10
	larvae	43.68	30.39–53.59	Y = –3.01+1.84 x	3	1.84±0.07
S. zeamais	adult	1.90	1.62–2.24	Y = –0.557+2.00 x	3	2.00±0.034

DF – degree of freedom; SE – standard error
Source: Denloye *et. al.* (2010).

We then investigated the insecticidal activity of powder, aqueous and ethanolic extracts of *Zanthoxylum zanthoxyloides* root bark against three important stored product pests. All the formulations were toxic to *C. maculatus, S. zeamais* and *T. castaneum* (Table 28). The powder formulation was effective in protecting maize and cowpea from insect infestation for 6 months. The ethanolic extract demonstrated residual property on *C. maculatus* over a post-treatment period of 336h (Figure 16). The results revealed that the botanical is an oviposition suppressant of *C. maculatus* (Tables 29).

The research findings were well received at the 10th International Working Conference on Stored Product Protection in Estoril, Portugal and it stimulated much interest most especially from crop protectionist from India where so much research have been carried out with the aim of isolating the active ingredient for commercial production.

Table 28. Acute toxicity of *Zanthoxyllum zanthoxyloides* to test insects

Formulation	Test Insect		95 % Confidence limits	Regression Equation	Degree of Freedom	Slope ± Standard Error
Powder	Species	48 hr LC_{50} (g/kg)				
	C. maculatus	0.050	0.007 – 0.228	Y = 2.77 + 2.124x	4	2.12 ± 0.75
	S. zeamais	0.012	0.0 – 0.055	Y = 1.54 + 0.803x	4	0.803 ± 0.042
	T.castaneum	0.041	0.007 – 0.111	Y = 1.806 + 1.303x	4	1.303 ± 0.088
Aqueous Extract		48 hr LC_{50} (g/L)				
	C. maculatus	0.834	0.633 – 1.042	Y = 0.127 + 1.605x	3	1.605± 0.034
	S. zeamais	0.334	0.26 – 0.427	Y = 0.586 + 1.232 x	3	1.232 ± 0.026
	T.castaneum	0.383	0.296 – 0.496	Y = 0.486 +1.168x	3	1.168 ± 0.025
Ethanolic Extract		48 hr LC_{50} (g/L)				
	C. maculatus	0.021	0.012 – 0.022	Y = 2.263 + 1.476x	3	1.476 ± 0.024
	S. zeamais	0.035	0.020 – 0.041	Y = 1.567 + 1.021 x	3	1.021 ± 0.021
	T.castaneum	0.085	0.029 – 0.096	Y = 0.486 +1.168x	3	3 1.021 ± 0.021

LC50 values with no overlap in their 95 % confidence limits are significantly different ($p < 0.05$).
Source: Denloye and Makanjuola (2010).

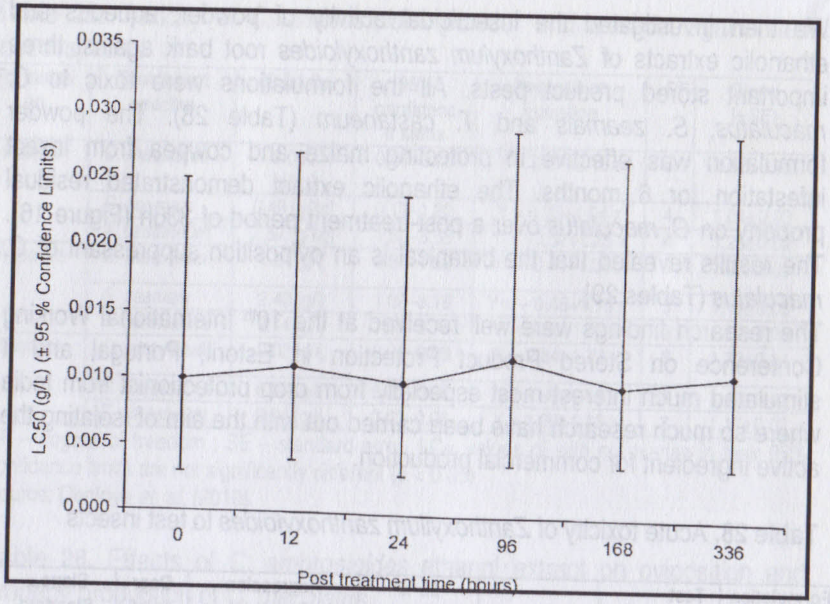

Figure 16. Persistence of *Z. zanthoxyloides* ethanol extract toxicity in treated cowpea grains
Source: Denloye and Makanjuola (2010).

Table 29. Effect of *Zanthoxyllum zanthoxyloides* on oviposition and progeny production of *C. maculatus*

Treatment	(g/L)	Mean number of Eggs laid (± SE)	Mean adult emergence (±SE)	Mean percent adult emergence (±SE)
Z. zanthoxyloides	(0.00)	93.30 ± 3.46 a	41.00 ± 2.58	43.95 ± 4.76
	(0.025)	53.00 ± 1.63 b	18.00 ± 3.16	33.88 ± 5.28
	(0.10)	21.00 ± 4.57 c	7.00 ± 2.45	32.86 ± 4.99

Column means bearing same superscripts are not significantly different (P > 0.05) by Least Significant Difference (LSD) Test.
SE = Standard Error
Source: Denloye and Makanjuola (2010).

Now, one may ask, 'what is novel about this work?' Well, unlike most researchers we have gone a step further by testing these botanicals in the field. The findings from these testing have shown that botanicals are moderately effective under our storage system. There is hope for the small scale farmer who can securely store his produce and is therefore no longer compelled to sell his or her crops immediately after harvest is over in a bid to avoid losses. Also, with the provision of the central laboratory temporarily cited in the Chemistry Department, we went further in our research by identifying some components of the plant which may be responsible for the insecticidal activity of the plant by two of my Ph.D students, Helen Negbenebor and Hilary Okoh who are at the final stage of their programme.

With all this advancement; from field trials to identification of active components that are responsible for insecticidal activity; we are collaborating with some chemists hoping that the active ingredient can be isolated, purified and synthesized for large scale use. Dr. Kasali of LASU, Drs. Olowu and Eshinlokun of Limpopo University, South Africa and Dr. Asekun of University of Lagos have all been of tremendous help. Our optimism has come since we were privileged to work so closely with a chemist. With us getting to the point of being manufacturers, it is our hope that this research may result in the establishment of a local insecticide industry.

CONTRIBUTIONS TO THE INDUSTRY

As an entomologist, thanks to the unique opportunity to carry out my sabbatical at Cadbury Plc, I was opportuned to contribute to grain storage management at the industrial level. Indeed it was an enriching experience in which, as displayed in prior lines, I was able to apply all my acquired knowledge to real life situations. I was given the free hand to look at and proffer solutions to problems experienced in the Lagos silos, the warehouses in Zaria and Kano as well as the finished factory products.

Though the results of my findings and recommendations cannot be presented here because it is the company's privilege document, I am nevertheless permitted to inform you that I was able to identify the problems that storage of grains posed to the company. Furthermore I made recommendations, some of which were effected before I completed my sabbatical year. I also carried out a research on some mysterious pests that affected some of the packaging that was used for one of their products. My contribution, I believe, made the company take some steps that protected the agricultural raw materials and products from the menace of insects.

Now I am pleased to bring to your attention that professional, industrial-based contributions such as mine have become increasingly important in the face of government's decision to ban cereal importation into Nigeria. With the ban on grain stimulating increased food production by many agro-allied companies; and grain production being seasonal with an off season of between 5 and 7 months, industries have now seen the need for grain storage at harvest when it is cheap. Hence, lots of emphases are presently being placed on grains storage management. For success at these storage practices, adequate infrastructure must be set in place with the right professionals taking charge and the entomologists ensuring that storage losses are minimal.

Some measure of success in the discussed storage practices have been achieved with companies having local inputs, such as syrup from locally grown sorghum, as substitutes for imported glucose. Note that most of the products in the market which are based on these local grains are in no way less acceptable than those obtained from imported malt and barley.

THE MOSQUITO-MALARIA PALAVER

Mr. Vice-Chancellor Sir, though this lecture has already gone great lengths at robustly addressing man's on-going battle with pests from the agric-entomology angle, I must however still bring to your attention other works of mine which address pest management problems from the medical entomology perspective. Hence we will be looking at man's raging battle with one of the most persistent pests of all time- Mosquitoes. Mosquitoes, as we all know, are linked to the dreaded malaria disease and it is worrisome to know that man uses a lot of insecticides in controlling them. Most often either the parasite or adult vector control method is adopted in controlling the malaria disease itself. However, in Africa, with malaria still a nagging menace, it appears that these efforts have taken us nowhere. Indeed it is a disease that has grown to become a huge epidemiological burden in Africa and it continues to cripple the economic development in our region. In Nigeria, the disease is responsible for 60% of outpatient visits to health facilities, 30% of childhood death, 25% of death of children under 1 year of age and 11% of maternal related deaths. Yes, due to malaria, our nation actually suffers a huge annual financial loss estimated to be about 132 billion naira in form of treatment, cost of prevention, loss of man-hour (Federal Ministry of Health, 2008).

Now I must say that, in truth, these disturbing statistics ought not to be so because, malaria is actually a treatable and completely evitable disease. Hence it is in line with this truth that attempts were made by Government in the past to half the malaria burden by 2010 and to ensure that the disease

no longer constitutes a public health problem (UNICEF, 2010). One of these attempts is through the World Bank Malaria Global Strategy and Booster (WBMGSB) program which is a 5-yearly plan with 3 years intense phase to support malaria control activities in countries suffering under the heavy burden of this disease. As it is believed that it is the right of every Nigerian to access highly preventive and curative care, the slogan of the program is 'a malaria free Nigeria'. It supports and identifies gaps in the country's strategic plans. Now it is important that I bring to your notice that a sum of 600 to 700 million US Dollars is earmarked for the intensive phase of the WBMGSB program in Africa through aggressive vector control. Of the stated sum, 180 million US dollars was allocated to Nigeria (Federal Ministry of Health, 2008). However in the midst of all these efforts and resource pooling, it is sad to note that the goal for a malaria free Nigeria is still far from being reached. This is because absent from most projects are the right people. To correct this, government would need to utilize and collaborate with knowledgeable and credible researchers who will render true service during researches and projects aimed at alleviating the malaria burden.

Use of synthetic chemical

Sometime in 2003, in addressing this mosquito-malaria challenge, Denloye and some of my research students evaluated some commonly used insecticides for the control of mosquitoes and cockroaches. All the insecticides were effective in killing mosquitoes, with 'High Power Raid' giving the best kill (Denloye *et al.* 2004).

'High Power Raid' was a new brand of formulated Raid that was apparently more effective than the earlier brands. Though the reason for the new brand was not fully understood by its end users, considering the fact that the earlier brands at some point turned less effective, it could only mean that the mosquitoes must have developed resistance to them. What the manufacturers have done was to produce more toxic insecticides which will initially prove to be very effective before eventually losing its strength due to selective pressure on the insect population which would have now developed resistance. This often is the genesis of cross and multiple resistances which compounding resistant problem.

Use of Botanicals in Mosquito Control

Laboratory studies using garlic (*Allium sativum*) aquaeous extracts on mosquito larvae and adults was carried out since there was paucity of information on the larvicidal and repellant effects of the crude extract of garlic. We found out that aqueous extract of garlic was most toxic to the first larval stage of *A. gambiae*. We recommended that extracts should be applied in stagnant water, especially in bathrooms and toilets with poor drainages where mosquitoes can breed (Figure 17). (Denloye *et al.*, 2003).

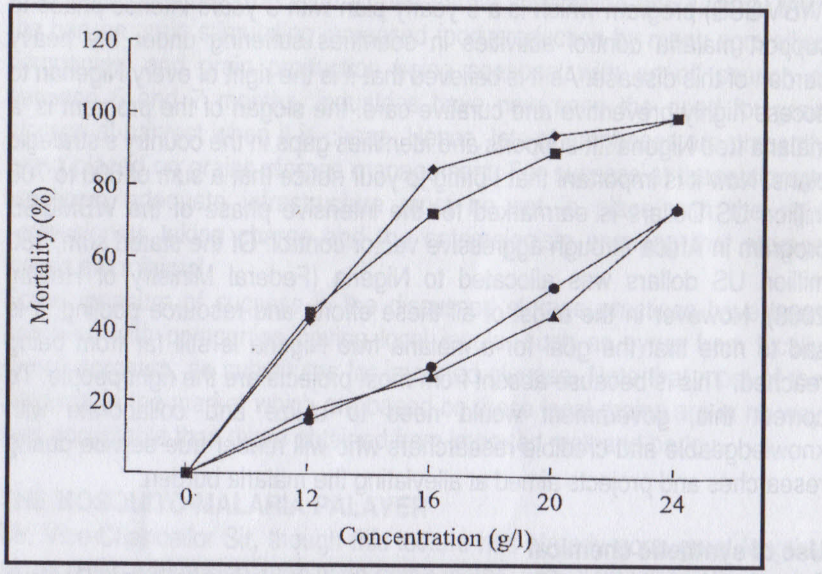

Figure 17. Mortality of *Anopheles gambiae* larvae exposed to different concentrations of aqueous garlic extract for 24 hours. Diamonds = first instar larvae: squares = second instar larvae; triangles = third instar larvae; circles = fourth instar larvae.
Source: Denloye *et al* (2003).

In another study, we were able to establish that *Chenopodium ambrosioides* extract and essential oil were toxic on all stages of *An. gambiae*. The extract was most toxic on first larval instar followed by the 4th larval instar. However with the essential oil, the fourth larval instar was the most susceptible followed by the first larval instar (Table 30).
Also the oil of *C. ambrosioides* was effective against the adult *An gambiae* adult with an LC_{50} of 1.01μl/L. This study highlighted the potential of *C. ambrosioides* in the control of *An. Gambiae.* Essential oil acted as a fumigant on the adults.

Table 30. Toxicity of *Chenopodium ambrosioides* extract to *Anopheles gambiae*

Treatment	*An.gambiae*	Time (h)	LC_{50} (mg/L)	Confidence limits	Slope ± *SE*	*df*	Probit line
Extract	1st instar	24	61.94	41.82 – 91.13	1.166 ± 0.02	4	*Y* = –2.09 + 11.66*x*
	2nd instar		123.62	76.72 – 197.78	0.69 ± 0.02	4	*Y* = –1.45 + 0.69*x*
	3rd instar		372.33	286.91 – 372.33	1.06 ± 0.01	4	*Y* = –2.71 + 1.06*x*
	4th instar		129. 93	105.04 – 160.52	1.58 ± 0.02	4	*Y* = –3.34 + 1.58*x*
Extract	1st instar	48	14.89	4.83 – 43.34	0.76 ± 0.02	4	*Y* = –0.88 + 0.76*x*
	2nd instar		41.05	21.16 – 78.56	0.83 ± 0.02	4	*Y* = –1.33 + 0.83*x*
	3rd instar		183.74	135.98 – 25.81	0.96 ± 0.01	4	*Y* = –2.16 + 0.96
	4th instar		18.90	8.68 – 40.45	1.04 ± 0.03	4	*Y* = – 1.33 + 1.04*x*
Essential Oil	1st instar	24	105.40	75.99 – 145.72	1.09 ± 0.02	4	*Y* = –2.203 + 1.09*x*
	2nd instar		437.59	293.68 – 554.21	0.71 ± 0.01	4	*Y* = –1.87 + 0.07*x*
	3rd instar		596.79	434.09 – 822.71	1.00 ± 0.02	4	*Y* = –2.77 + 1.00*x*
	4th instar		248.68	210.78 – 293.31	1.18 ± 0.02	4	*Y* = –4.29 + 1.79*x*
Essential Oil	1st instar	48	90.75	60.71 – 134.92	0.95 ± 0,01	4	*Y* = –1.85 + 10.95*x*
	2nd instar		135.24	95.97 – 189.93	0.93 ± 0.01	4	*Y* = –1.99 + 0.93*x*
	3rd instar		141.71	103.30 – 193. 91	1.00 ± 0.02	4	*Y* = –2.14 + 1.00*x*
	4th instar		36.62	23.97 – 55.53	1.45 ± 0.03	4	*Y* = –1.27 + 1.45*x*
Oil vapour* Adult		24	1.01	0.52 – 1.73	0.87 ± 0.03	1	*Y* = – 0.22 + 0.87*x*

*: The unit of LC_{50} of oil vapour is μl/L
Source: Denloye *et. al.* (2009).

My research team then moved on to screening 29 medicinal plants for their insecticidal activity against *An. gambiae* and *Aedes aegypti* larvae and adults (Plates 16 and 17). We were able to identify components in the most toxic plant that were likely to be responsible for the insecticidal activity on the mosquito species.

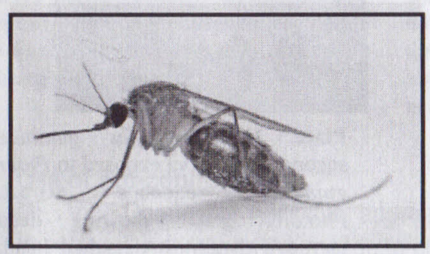

Plate 16. *Anopheles gambiae* adult

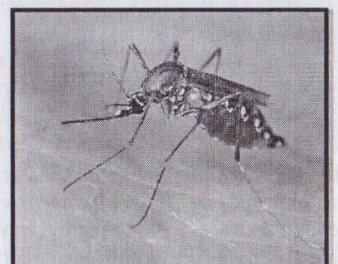

Plate 17. *Aedes aegypti* adult

We were able to establish that using dried plant matter was more effective than fresh plant matter and that the extracts obtained using Maceration method were more toxic than extracts obtained using soxhlet extractor. The active ingredients might have been denatured most probably due to heat applied during extraction using soxhlet. This might be responsible for differences in results often reported by researchers since it was established from our findings that the method of extraction does influence the potency of the extract.

Bioassays carried out on the mosquito larvae showed morphological distortion of the larvae to varying degrees depending on the plant species used as shown in plates 18-25 (Okoh *et. al.* Unpublished).

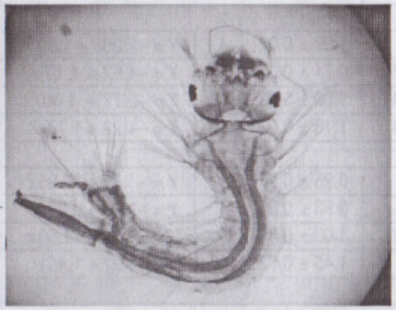

Plate 18: Normal *A. aegypti* second instar larva with no morphological distortions (control)

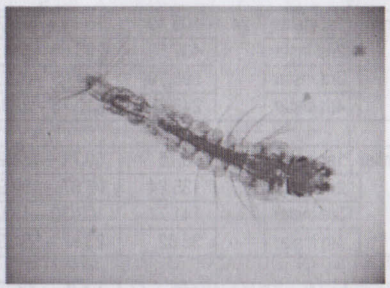

Plate 19: Normal *A. gambiae* second instar larva with no morphological distortions (control)

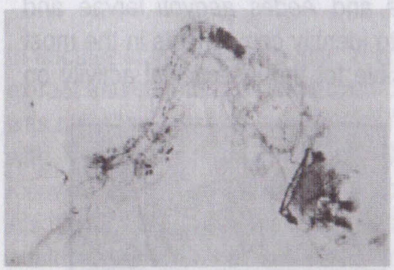

Plate 20. *Aedes aegypti* second instar larva exposed to *Piper guineensis* aqueous extract. Photomicrograph showing dead larvae with transparent abdomen and constriction of midgut contents into only two segments of the abdomen.

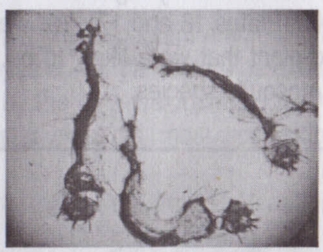

Plate 21. *Anopheles gambiae* second instar larva exposed to *Piper guineensis* aqueous extract. Photomicrograph showing dead larvae with almost detached head, wilting body hairs, constricted and distorted abdomen and highly dense, collapsed midgut spilling its content into the tail region.

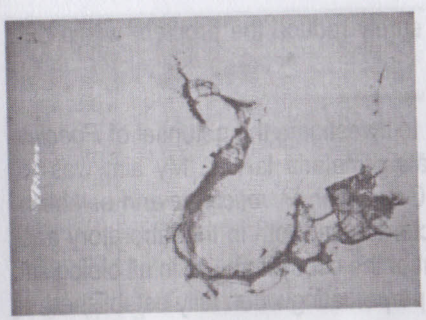

Plate 22. *Aedes aegypti* second instar larva exposed to *Nicotiana tabacum* aqueous extract. Photomicrograph showing dead larva with wilting body hairs, distorted and shrunken cuticle, disproportionate to the enlarged head. The gut is detached from the body wall due to constriction and the tail is distorted with loss of hairs.

Plate 23. *Anopheles gambiae* second instar larva exposed to *Nicotiana tabacum* aqueous extract. Photomicrograph showing dead larvae with almost enlarged head, highly dense abdominal region with poor differentiation of the midgut, and loss of thoracic and abdominal hairs. There is also no differentiation of the thorax from the abdomen and a distorted tail with loss of anal gills and hairs.

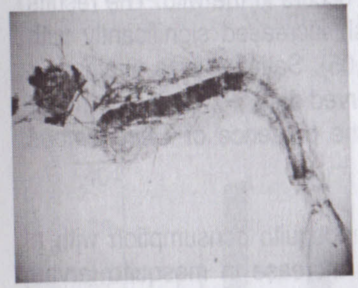

Plate 24. *Aedes aegypti* second instar larva exposed to *Zanthoxylum zanthoxyloides* aqueous extract. Photomicrograph showing dead larvae with highly dense head region. There is no differentiation of thorax from the abdomen due to enlarged upper segments.

Plate 25. *Anopheles gambiae* second instar larva exposed to *Zanthoxylum zanthoxyloides* aqueous extract. Photomicrograph showing dead larvae with complete loss of hair (frontal, thoracic, abdominal and fossate), highly distorted heads and thorax, constricted abdomen and collapsed midgut. The tail is also distorted with loss of anal gills.

Use of Bio-control agent

Mr. Vice-Chancellor Sir, this approach which our team of researchers developed, addresses the mosquito challenge through the use of predators so as to eventually minimize the use of synthetic chemicals in stagnant water within the ecosystem. This will surely reduce the problem within our water bodies.

I got Anogwih – a Ph.D staff candidate to investigate the potential of *Poecilia reticulata,* a larvivorous fish, in regulating malaria larvae. My aim was to improve the predation potential of the Guppy fish *P. reticulata* and establish it as a bio-control agent of malaria vector larvae, both in the laboratory and the field, since it is a natural component of the ecosystem. As in all biological control systems, we hope it will be self perpetuating when fully established.

The above method will be a useful tool in integrated vector management as it will obviously bring about a reduction in mosquitoes at the breeding source. In the long run, compared to insecticide usage, it will be self sustaining without any hazard to the environment.
After analysis of the ecosystem, the natural environment of guppy fish was simulated to estimate an efficient guppy-mosquito larvae density that is adequate for bio-control. We thereafter evaluated the fish predatory pattern in the presence of alternative preys, just as it occurs in the wild. The results showed that prey consumption of guppy fish increased significantly with predator-prey density and time interval ($P<0.05$). Satiation was attained at predator-prey density of 1:30. It was observed that *P. reticulata* never ceased feeding on mosquito larva despite the presence of *Chironomous* larvae (Figure 18).

There was variation in the peak periods of mosquito consumption with a decline in feeding even when there was an increase in mosquito larvae density. Shoaling behavior of fish, avoidance of immobile larva, low foraging when single and competition for prey when paired were some of the behaviors observed during study (Figure 19). It was also observed that the fish spent more time on water surface. We therefore concluded that under field conditions, the presence of an alternate prey may affect the efficiency of the guppy, as mosquito control agents. It is therefore important that we obtain the right estimate of predator-prey density to ensure that it is effective in controlling the larvae.

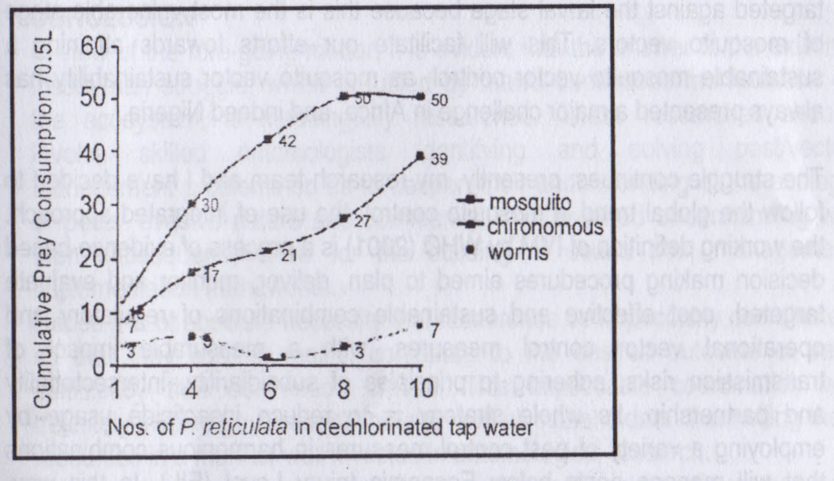

Figure 18. *P. reticulata* – prey interaction under 6 hours observation
Source: Anogwih and Makanjuola (2010).

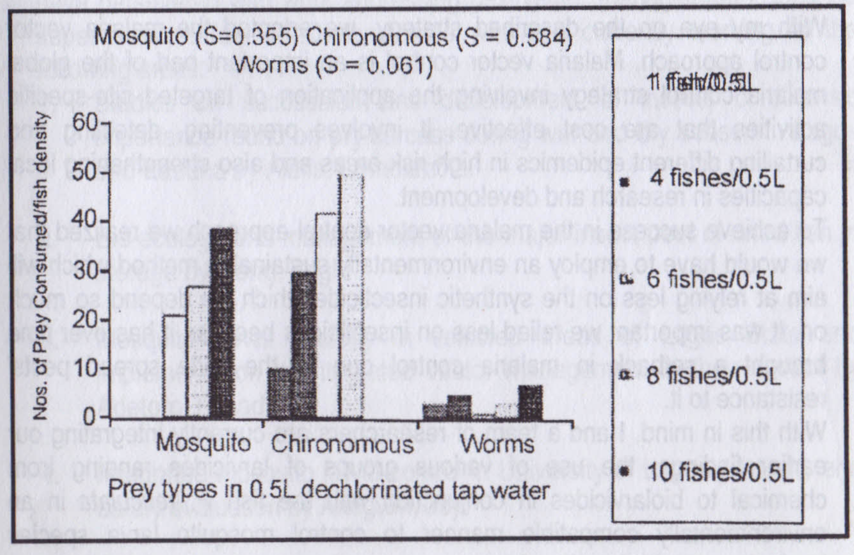

Figure 19. Guppy feeding preference within 6 hours.
S = Manly's Selectivity Index
Source: Anogwih and Makanjuola (2010).

INTEGRATED VECTOR MANAGEMENT

Mr. Vice-Chancellor Sir, from the foregoing, we have successfully established some control methods against mosquito larval species. I must state here that all our earlier struggles against the mosquito vector were targeted against the larval stage because this is the most vulnerable stage of mosquito vectors. This will facilitate our efforts towards attaining a sustainable mosquito vector control, as mosquito vector sustainability has always presented a major challenge in Africa, and indeed Nigeria.

The struggle continues: presently, my research team and I have decided to follow the global trend in mosquito control: the use of integrated approach. the working definition of IVM by WHO (2001) is a process of evidence-based decision making procedures aimed to plan, deliver, monitor and evaluate targeted, cost effective and sustainable combinations of regulatory and operational vector control measures, with a measurable impact of transmission risks, adhering to principles of subsidiarility, intersectoriality and partnership. Its whole strategy is to reduce insecticide usage by employing a variety of pest control measures in harmonious combinations that will manage pests below Economic Injury Level (EIL). In this way, chemical control will play only a supportive role.

With my eye on the described strategy, we adopted the malaria vector control approach. Malaria vector control is an important part of the global malaria control strategy involving the application of targeted site-specific activities that are cost effective. It involves preventing, detecting and curtailing different epidemics in high risk areas and also strengthening local capacities in research and development.

To achieve success in the malaria vector control approach we realized that we would have to employ an environmentally sustainable method which will aim at relying less on the synthetic insecticide which we depend so much on. It was important we relied less on insecticides because it has over time brought a setback in malaria control due to the wide spread pests' resistance to it.

With this in mind, I and a team of researchers are currently integrating our earlier findings: the use of various groups of larvicides ranging from chemical to biolarvicides in conjunction with the fish *P. reticulata* in an environmentally compatible manner to control mosquito larva species beginning with University of Lagos campus for onward adoption into large scale larviciding practices.

CONCLUSION

In view of the fore-going matter, it is evident that the answer to the existing insect-man struggle, which is fueled by man's continuous manipulation of the ecosystem, is meaningfully researched. These researches should involve skilled entomologists identifying and solving pest/vector management problems so as to deepen their understanding of the ecology of pests' evasive nature and community. The acquired understanding will then subsequently allow for the building of sound pest management implementation frameworks.

Hence it is of absolute necessity that researches be impeccably coordinated so that they can, in reality, contribute to the desired outcome of self-sufficiency that our nation craves. This impeccable coordination will definitely involve government, industry and all stakeholders channelling their resources in a manner well invested in entomological research.

In summary, it can be concluded that though the struggle continues between insects and man, there is yet still hope for man. With this hope in mind, I have persevered with work addressing pest/vector management issues via supervision of four Ph.D candidates who are currently working in the following areas:

1. Studies on succession and development of insects of forensic importance found on pig carcass during wet and dry season in Lagos and Kaduna by Alafia, Oyindamola.

2. Bio-ecology and management of the major insect pest of dried fish in storage by Isong, Bright.

3. Mosquito larval ecology in selected areas of Lagos State and implementation of integrated vector management in their control by Adetoro, Fouad.

4. Integrated mosquito larval control in University of Lagos – toxicity and safety evaluation by Anogwih, Joy.

RECOMMENDATIONS

In view of the fore-going discussion which visibly highlights the struggles existing between man and insects, I make the following recommendations with the belief that when effectively applied, the results would give man the supremacy he so desires.

RECOMMENDATIONS TO THE GOVERNMENT

These are my recommendations to the government:

1. The government should be at the forefront of the development of sound integrated pest management strategies in the country. All known stakeholders (researchers, producers of insecticides, representatives of farmers, cooperatives, public health officers etc.) should be involved in development and execution of strategies.
2. The government need to give adequate support (by funding and provision of infrastructures) to entomologists in carrying out field trials of insecticides in the determination of effective/applicable dosages. By this wastages of materials and inputs will be minimized.
3. At the federal level, the government should set up a central body that will collate all developmental efforts of practicing entomologists nationwide with the goal of periodically publishing articulated information that will be helpful to all stakeholders in the business of insect control and integrated pest/vector management – by this a data bank of relevant information will be available to all.
4. Effective information dissemination of research findings, changing government policies as related to pest/vector management, and newly developed pest/vector management techniques need to be carried out. By use of cost effective modern communication elements, the knowledge base of agricultural and public health practitioners will be raised.
5. Well trained extension entomologists should be hired by the various ministries of agriculture and health. These scientists are to help farmers and public health officers in the appropriate usages of insecticides and also practically teach them the most modern techniques of insect controls and pest/vector management.
6. Government working in close collaboration with the reputable Entomology Society of Nigeria, ESN, a monitoring mechanism by which quality of pest control services rendered across the country can be established. This will confirm to all and sundry that the government is appreciative of the economic importance of effective pest/vector management. The government can even go further to set up a commercially viable pesticide regulating service which promotes awareness and provides advisory services on insect control and pest/vector management in general.

RECOMMENDATIONS TO UNIVERSITIES

Before giving my recommendation to universities, I must first commend University of Lagos for intensifying her research through the provision of

research grants and the equipping of the temporary site of Central Research Laboratory. This has indeed made research within the system more in depth and purposeful. These are my recommendations to the universities:

1. Universities, through the departments of Zoology and Faculties of Agriculture/ Medicine should urgently design programmes for the training of "extension entomologists" who will be adequately equipped to significantly contribute in the growth of food production and public health.
2. Universities should actively initiate and provide collaborative work with the industries in pests control on stored food products. Grains generally stored in huge silos across the country are often attacked by pest resulting in huge financial losses. Highly experienced entomologists (along with their research assistants and students) can make huge contributions if properly mobilized.
3. Some certain chemical processing industries can be encouraged to work with our institutions to develop and produce variants of insecticides (especially botanical based) that will address our peculiar local needs. Properly designed development work with the potential of commercial gain will surely interest our entrepreneurs/investors.

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