OSUN STATE UNIVERSITY

INAUGURAL LECTURE

SERIES

005

WHOSE WORLD, MAN'S OR INSECT'S?

BY

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The Vice-Chancellor,

The Registrar and other Principal Officers,
The Provost, College of Science, Engineering and Technology,
Provosts of other Colleges, Deans and Directors,
Head, Department of Biological Sciences,
Members of Senate and other colleagues,
My Lords Spiritual and Temporal,
Friends of the University/ Special Guests,
Distinguished Academics,
Distinguished Ladies and Gentlemen,
Gentlemen of the Press,
Students of Osun State University

1. Introduction

The topic of my lecture this afternoon "Whose World, Man's or Insect's?" will dwell on the struggle for the domination of the ecosystem between Man and the Ubiquitous invader- Insects- often considered as Man's greatest challenger, and Man's utilization of various strategies to subdue the insects. This will dovetail into the highlights of the contributions of my research work over the years and offer suggestions that will guarantee a better future for all.

In a topic of this nature, it is necessary to get a clear perspective of the terms that will be encountered during the course of the lecture. I will therefore start with the definitions of terms and take this august audience through the struggle for the domination between these two great occupiers of the ecosystem.

Definitions

World

Wikipedia, the free encyclopedia defined 'World' as a common name for the whole of human civilization, specifically human experience, history, or the human condition in general. Wikipedia went further to delineate the term 'World' on philosophical and theological contexts, referring to the whole of the physical universe as philosophical and the material or the profane sphere, as opposed to the celestial, spiritual, transcendent or sacred as theological. Several definitions also exist in literature on the word 'World' (Bowring and Housh, 1995; Patterson, 1999; Yin *et. al.,* 2002), but for the purpose of this lecture, 'World' will refer to the planet earth as a physical entity inhabited by Man.

The earth is believed to have been formed out of a disk-shaped mass of dust and gas left over from the formation of the sun some 4.54 billion years ago and that life appeared on its surface within one billion years (Dalrymple, 1991). It is the fifth largest of the eight planets in the solar system and the third planet from the sun; it is the only planet where life is known to exist and the home to millions of species, including Man (May, 1988; Purves *et. al.,* 2001).

Who is Man?

The Oxford Dictionaries Online gave many definitions of the term **Man** and this included reference to Man as members of the group that comprises modern humans and their ancestors (Genus: *Homo*) or in the general context the human race.

Man is believed to have evolved from the Australopithecines, bipedal species that occurred in the Plio-Pleistocene era (5 million years ago), dentally similar to man but with brain size not much larger than modern apes (Larry *et. al.*, 2005). The diversion of Man from the Australopithecines occurred about 2.3 to 2.4 million years ago in Africa (Stringer, 1994). Scientists estimated that humans branched off from their common ancestor with chimpanzees, two extinct species of ape in the genus Pan, about 5 to 7 million years ago.

Although several theories and submissions have been postulated on the origin and evolution of Man, the generally agreed position is that Man evolved about 2 million years ago.

Insects

Insects are segmented six-legged animals that belong to the category of invertebrates in the Phylum Arthropoda (Stork, 1988). Members of this phylum have jointed appendages, segmented bodies and a hard outer covering, called exoskeleton. Two other well-known members of this phylum are the Crustaceans, which include crabs and crayfish, and the Arachnids, which contain the spiders, mites, ticks and scorpions.

In the adult forms, insects typically have three pairs of legs, one pair of antennae and in most cases, two pairs of wings (Figure 1).

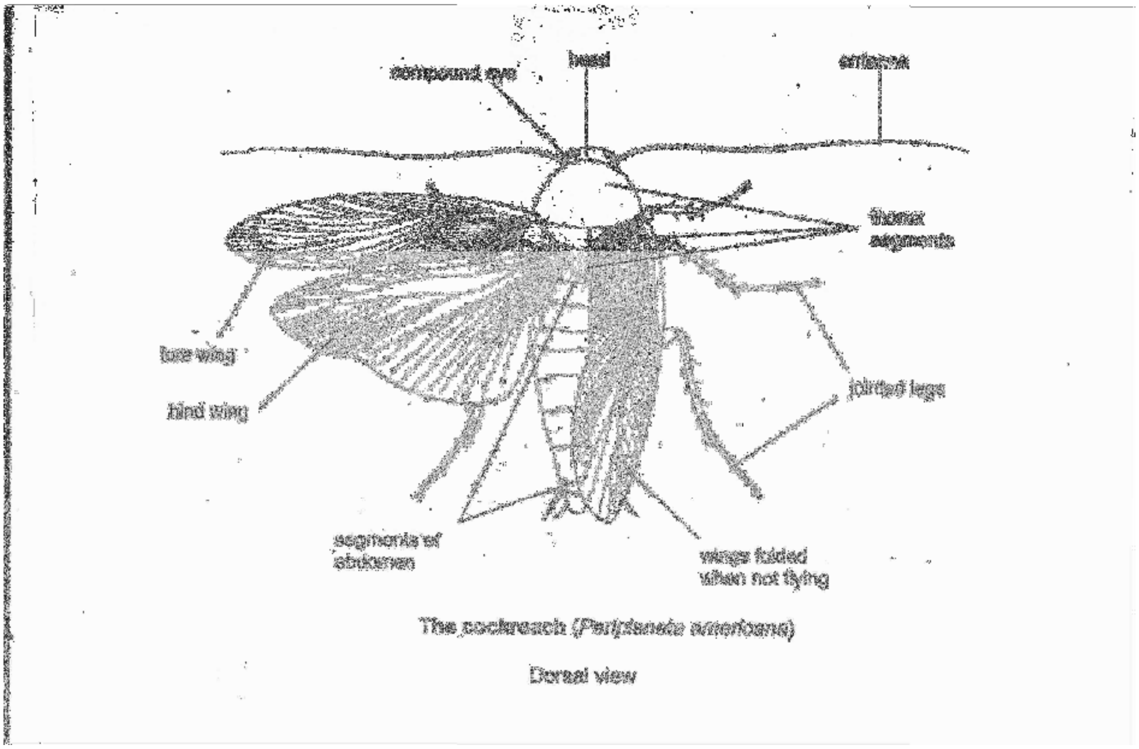

Fig. 1: External features of *Periplaneta americana*

Insects are differentiated from other arthropods by the presence of a distinct head, thorax and abdomen; by their digestive tract which is of fore-, mid- and hindguts and the presence of salivary gland in the mouth; by the possession of a slender mid-dorsal heart and an anterior aorta, with no capillaries or veins; by the possession of spiracles and branched trachea which are lined with cuticle and which serve respiratory functions; by the presence of two to many malphigian tubules used for excretion; by the possession of a brain with fused ganglia and double ventral nerve cord with segmented ganglia often concentrated anteriorly, Romoser (1981).

Insects are believed to have originated in the Silurian period and the earliest known insect fossils were reported to date back to the Devonian period (Speight *et. al.*, 1999). However, it was only recently that their increased diversity became noticeable with the evolution of the flowering plants about 135 million years ago.

From the origin and evolution of Man and Insects, it had long been concluded that Insects were among the first animals to appear on land and are generally considered to be the most successful groups of animals because they live in the greatest variety of habitat, eat the greatest variety of food, have the greatest number of species and possess the greatest diverse means of locomotion. Could Man therefore claim to own the Earth, as it is often assumed?

Because Man and Insects inhabit planet Earth, the co-habitation of Man and Insects on this planet will be influenced by the kind and type of relationships that exist between them and whether such relationship create critical areas of friction, since they both have to compete for all that is necessary for the survival of each group, including food, water, nutrients and even space. It is therefore pertinent to examine the relationships that exist between Man and Insects.

2. <u>Relationships between Man and Insects</u>

The relationships between Man and Insects can be discussed under two broad headings: those that enhance food production and confer significant advantage on Man and his possession (**Beneficial relationship**) and those that threaten food production and have far-reaching negative effects on Man and things valued by him (**Injurious relationship**). Examining these relationships will no doubt enhance our understanding of the roles of Insects in the life of Man.

<u>Beneficial Relationships</u>

A great number of insects are beneficial to Man. Of over a million species of insects described (Pyle *et. al.*, 1981), only a few have negative effects on man. Insects are beneficial to Man in several ways and these include the following:

Pollination

Insects are very important as plant pollinators for the production of many crops and fruits consumed by Man. Pollination is by far the most useful activity carried out by insects, and insects pollinating crops include Honeybees *Apis mellifera*, bumblebees *Bombus terrestris*, hover flies, wasp, *Xylocopa* species, oil palm pollination weevil (*Elacidobirus kamerunicus*) and butterflies. One-third of the total human diets (citrus, cabbage, melon, cucumber, sunflower, etc) are derived directly or indirectly from insect pollinated plants. The worldwide economic value of insect pollination by bees mainly, was estimated by German and French scientists as €153 billion in 2005 for the main crops that feed the world, amounting to 9.5% of the total value of the world agricultural food production (Science Daily, 2008). In the study, the consumer surplus loss of between €190 to €310 billion was also estimated for the disappearance of pollinators. The results of this study, published in the Journal of Ecological Economics, indicate the significant contributions of insects to man's food production. In a recent report, the use of honeybee for mass pollination in a farm in Pakistan yielded 22 percent increase in production of sunflower (Azin, 2011).

A combination of enterprise between a beekeeper and a crop farmer can earn the farmer 3.5 times more from pollination than the beekeeper earns from the honey. Table 1 shows the significant yield increases for seeds and fruits schematically per hectare and per hive, with pollination fee included.

Table 1: Extra income per hive through pollination

	Land Area (ha)	Hives hired	Crop Yield (kg/ha)	Honey yield (kg/ha)	Profit farmer		Profit bee-keeper
					Total €	Per colony €	€
Sunflower	1	0	500	100	500		100
Sunflower	1	2	850	100	850	850-500/2=175	100+(2x25)
Watermelon	2	0	12,000	50	2,400		50
Watermelon	2	4	20,000	50	4,000	(4,000-2,400)/4=400	50+(4x25)

Source: Marieke *et. al.* 2005

It was estimated that if the beekeeper is also the farmer of the crop, his or her income will be much higher.

Biodegradation and Soil Enrichment

Insects are agents of biodegradation ensuring the recycling of dead plant and animal tissues. Different species of insects such as crickets, maggots, carrion beetles and rove beetles feed and decompose plant and animal remains, thus enriching soil fertility. The spring tails and a variety of heavily built beetles live on organic remains and help to recycle the nutrients that plants use (Encarta Encyclopedia, 2009). The Dung Beetles assist man in degrading animal droppings or dung, rolling it into balls and burying them. The roles played by these insects are of importance in the recycling of waste and dead plant and animal tissues that would have caused the pollution of the environment and the outbreak of diseases. For instance, the introduction of dung beetle from Africa into northern Australia prevented, within a short time, the build-up of buffalo dung on grazing land which could have killed the grass fed on by the animal and created breeding grounds for flies (Elzinga, 2004).

Silk Production

The Silkworm Moth, *Bombyx mori,* the insect that produces mulberry silk, is a domesticated variety of silkworm which has been exploited for over 4000 years by man. The art of silk production is called sericulture. Ullal and Narasimhanna (1987) defined sericulture as an agro-industry, the end product of which is silk. Although there are four major kinds of natural silk which are commercially known and produced, the mulberry silk is the most important and accounts for up to 95% of the world production of silk; the other three, categorized as non-mulberry silk include eri silk, tasar silk and muga silkworm (Huang *et. al.*; 2006). The local silk fabric referred to by the Yorubas as "Sanyan" or "Aso oke" is produced by the local species of the silkworms.

Silk has played an important role in the economic life of man since its discovery some 4000 years ago. It has been traditionally associated with the socio-economic life of many Asian and central Asian countries and has continued to reign supreme as the queen of textiles. Silk is universally sought after for its elegance and colours and normally used for important ceremonies in the south western part of Nigeria. Silk has always had an aura of royalty. It is a royal wear by the traditional rulers in Yorubaland. It enriches religion and ritual, and is considered the yarn of life. The Empress of Japan still feeds silkworms on the palace grounds each spring, and the Queen of Thailand sponsors silk-making lessons in the palace (Wei, 1993; Good, 2009; Ball, 2009).

Honey Production

The honey bee, *Apis melifera adansonii,* is primarily known for the production and storage of bee honey. Only seven species of honey bees are currently recognized (Engel, 1999) and they represent only a small fraction of approximately 20,000 known species of bees. Bee honey is a mixture of sugars and other compounds, made from flower nectar and is produced by bees as a food source. It contains about 38.5% fructose and about 31% glucose with maltose, sucrose and other carbohydrates (Martos *et. al*., 2000). It also contains trace amount of vitamins and minerals and small amounts of antioxidants (Gheldof *et. al*., 2002) (Table 2). It is a supersaturated liquid that contains more sugar than can typically be dissolved by water at ambient temperatures. It is also a supercooled liquid that will not freeze at low temperatures, but rather increase in viscosity and become thick and sluggish. Honey is consumed by Man and used as a sweetener and flavouring in the food and beverage industries. It is also used in religious ceremonies and in the treatment of ailments.

Table 2: Nutritional Composition of Bee Honey

Nutritional value per 100 g (3.5 oz)

Energy	1,272 kJ (304 kcal)
Carbohydrates	82.4 g
Sugars	82. 12 g
Dietary fiber	0. 2 g
Fat	0 g
Protein	0 3 g
Water	17. 10g
Riboflavin (vit. B_2)	0. 038 mg (3%)
Niacin (vit. B_3)	0. 121 mg (1%)
Pantothenic acid (B_5)	0. 068 mg (1%)
Vitamin B_6	0. 024 mg (2%)
Folate (vit. B_9)	2 µg (1%)
Vitamin C	0.5 mg (1%0
Calcium	6 mg (1%)
Iron	0. 42 mg (3%)
Magnesium	2 mg (1%)
Phosphorus	4 mg (1%)
Potassium	52 mg (1%)
Sodium	4 mg (0%)
Zinc	0. 22 mg (2%)

Shown is for 100 g, roughly 5tbsp.

Percentages are relative to US recommendations for adults.

Source: USDA Nutrient Database

Biological Control

Insects have been used in the control of other insects that are pests of crops or that attack man or things valued by Man (a process termed Biological Control). The major weapons of biological control are parasites, predators, pathogenic microbes and competing species. Biological Control came into prominence with the successful control of the cottony cushion scale, *Icerya purchasi* on citrus in California by the predatory coccinelid beetle, *Rodoelia cardinalis* imported from Australia. Since then over 100 pest species have been controlled using this method. The effectiveness and efficiency of biological control agents in the control of pests of agricultural and veterinary importance have amply been demonstrated in several studies (Beddington, *et. al.* 1978; Lawton and McNeill, 1979; Hairston, 1989; Crawley, 1992). The Ladybirds, for example, is an insect that feed on aphids that are pests of vegetables, and the hoverflies and wasps attack harmful insects of crops in gardens. These insects act as predators feeding on the pests or as parasitoids, laying eggs in the pest insects, thus providing food for its developing young. A particularly outstanding example is the successful control of the water hyacinth by the introduction of two natural enemies, a weevil, *Neochetina eichhorniae* and a mite, *Orthogalumna terebrantis* (Van Schoubroeck *et. al*., 1989).

Entomophagy and Entomotherapy

Many insects are food for birds and animals, including Man. The eating of insects by Man is known as Entomophagy. Over 1000 insects in about 370 genera are consumed by man (Defoliart, 1989; Van Huis, 2003). For instance, the Australian Aborigines have been eating insects from time immemorial as a delicacy in their diet. In Nigeria, termites, grasshoppers, *Z. variegatus*, crickets, Rhinoceros beetle, *Oryctes* spp. and *Rhychophorus* spp. are delicacies in the South Western and Niger Delta regions of the country (Ene, 1963; Adedire and Aiyesanmi, 1999; Van Huis, 2003). In fact, Idowu *et. al.* (2004) advocated the use of *Z. variegatus* as a supplementary protein source and inexpensive substitute for meat in a developing country like Nigeria while Ademolu, *et. al*. (2010) suggested the inclusion of the earlier instars of this insect in the diet of humans and farm animals. Apart from consumption of insects as source of protein by humans (Idowu and Modder, 1996; Ajayi and Adedire, 2007), the use of insects in the treatment of ailments mostly in the rural areas where the large proportion of the population engage in farming has multiplying effects on food production. Honey from honey bees (*Apis* species) has been used for the treatment of many ailments (Omoloye and Akinsola, 2006; Omoya and Akharaiyi, 2010). The sting from honey bees has also been used for the treatment of rheumatics and arthritis (Mbah and Amao, 2009). Besides medicine, these organisms have also played mystical and magical roles in the treatment of several illnesses in a range of cultures (Wang *et. el*., 1987). Science has already proven the existence of immunological, analgesic, antibacterial, diuretic, anesthetic, and antirheumatic properties in the bodies of insects (Zhang, *et. al*., 1991; Banjo *et al*., 2003; Eraldo, 2005).

Forensic Investigations

Insects and their arthropod relatives have been used to aid legal investigations. This is called Forensic Entomology. Forensic entomology is a recent branch of entomology that utilizes the study of insects and other arthropods that inhabit the flesh of decomposing bodies to determine the circumstances of death of a victim, such as the time of death and even in some instances, the location of the crime if the body has been moved from this location. It thus can be used to determine the time of death, commonly known as postmortem interval (PMI) of a victim of crime (Catts and Goff, 1992). Insects such as flesh flies and blowflies (Diptera), trogid beetles (Trogidae), hide and skin beetles (Dermestidae), rove beetles (Staphilinidae), carrion beetles (Silphids), spring tails and ants are usually associated with the presence of dead bodies and thus play significant roles in forensic investigations. This branch of entomology was first recorded in 1247 AD by Song Ci, a Judicial Intendant, who laid the fundamentals for modern forensic entomology. Since then, forensic entomology has gained acceptance and wide usage in the developed world (Benecke, 2001). However, its use in the developing countries is still at its infancy.

Scientific Research

The Fruit Fly, *Drosophila melanogaster*, is one of the most valuable organisms used by Man as models in scientific research and has assisted Man in great scientific discoveries in the areas of genetics and developmental biology, thus leading to major breakthroughs in Medicine and the award of the Nobel prize in medicine/physiology to Ed Lewis, Christiane Nusslein-Volhard and Eric Wieschaus in 1995. This insect lends itself for the study of genetics and evolution because of its ability to breed rapidly and produce very many generations per year in the laboratory. It was used to discover that genes were related to proteins and in embryonic development studies (Patterson, 1999; Markow & O'Grady, 2005).

Harmful Relationships

Insects that are harmful to Man are referred to as **Pests**. An insect is considered a pest when it causes annoyance or injury to man, his possessions or his interests (Kumar, 1984). The injury, which may result from direct or indirect attacks by the insects, may be physical, medical or economic. Physical injury results from bites or stings, medical injury results from illness or diseases while economic injury results from damage or monetary loss to things valued by man. The harm and/or damage caused by these insect pests and the value placed on such by man constitute the most important aspect of a pest species.

Depending on the severity of the attack and/or the damage caused, insects can be categorized into Key or Major Pests, Minor Pests, Occasional or Sporadic Pests and Migrant Pests. **Key or Major pests** are those insects that occur perennially and cause serious and persistent economic damage in an ecosystem in the absence of an effective control measures (examples include the Elegant grasshopper, *Zonocerus* *variegatus*, the Mexican bean beetles, *Epilachna varivestis* and the corn earworm, *Helicoverpa zea*, to mention a few). **Minor Pests** include insects found living and/or ovipositing in or on plants without causing economic damage (examples include the cowpea leaf beetle, *Lagria villosa*). **Occasional or Sporadic Pests,** are those insects that become pests only on certain occasions when ecological, environmental and cultural conditions provide special opportunities for them to increase in population and become damaging (examples include fall armyworms, *Spodoptera frugiperda*, potato leafhopper, *Empoasca fabae* and pharaoh ants, *Monomorium pharaonis).* **Migrant Pests,** include those insects that migrate from one zone to the other where they cause economic damage (examples include the African locust, *Locusta migratoria)* (Kumar, 1984).

Major pests are usually the targets of pest control operations. They are typically small, mobile and have high reproductive potentials but constitute not more than 1% of insect populations. They include also insect pests of medical and veterinary importance and those that spread diseases among plants. Control actions must be planned yearly for pests under this category to prevent major loss or injury. Minor pests are usually not abundant enough to cause economic damage or injury and are therefore rarely controlled while migrant pests do not cause damage in their original location but move to another location to cause economic damage.

3. Causes of Harmful Relationships

The major causes of the harmful relationships between Man and Insects are largely due to the influence of Man on the ecosystem through a number of interventions. Man's intervention in changing the structure and component of the ecosystem, knowingly or unknowingly, had resulted on many occasions, in increased population of insects beyond levels that are tolerable, thus creating serious pest problems (Waage, 1993). For example, the cultivation of a single plant species over a large acreage of land (**monoculture**), has brought about the reduction in the number and species of crops planted and the simplification of the ecosystem thus providing excellent environment for the development of pest species that found the crop ideal for their growth and development resulting in the increased population of these insects beyond acceptable tolerant levels (Strong *et. el.*, 1984). Coupled with this are the changes in crop management practices and the unguarded and indiscriminate use of insecticides which often result in the destruction of non-target populations of natural enemies (parasites and predators) of pest species, and cause outbreaks of new pest species that were previously held in check by parasitism or predation. The advent of modern means of transportation by man has also contributed to the creation of pest situations since pest insects that were once prevented by geographical barriers can now be carried as hitch-hikers on man and his produce (Romoser, 1981).

The problem of climate change which results from man's pollution of the environment has led to the prolific breeding of many insect vectors. The persistent flood being experienced in many parts of world is one of the direct effects of climate change and land use/ land cover. The flooded environment creates ample opportunities for insect vectors, such as mosquitoes to thrive. Our just concluded study on impact of environmental changes on the epidemiology of mosquito-borne diseases in Osogbo metropolis using Geographic Information System and Remote Sensing showed that settlement and flooded areas had increased within five years by 62.2% and 79.1% respectively. This increase would have plausibly created a conducive breeding sites for mosquito vectors and possibly responsible for the high spate of malaria reported in the metropolis in recent time (Adefioye *et al*., 2007)

The quest of man for survival through inter-regional business activities is also part of the factors worthy of mentioning. The appearance of *Aedes albopictus* (Asian tiger mosquito)*,* which has been implicated in the transmission of some deadly and life-threatening disease in Nigeria such as dengue and *Wuchereria bancrofti* was reported to have been transported from Asia to the country through fairly used tyres (popularly known as Tokunbo tyres) (Mbanugo and Okpalaonuju, 2003; Adeleke *et al*., 2008).

4. Effects of Harmful Relationships

The detrimental impacts of insect pests and their attendant economic loss on field and stored products have been extensively studied by many researchers. The first attempt to estimate crop losses due to various pests on global scale was made by Cramer (1967). Subsequently, Oerke *et al.* (1994) undertook an extensive study to estimate losses in principal food and cash crops. Yield and economic losses of field and stored products due to insect pests attack ranged between 20-50% (Singh, 1990; FAO, 2002; Zakka *et. al*., 2009) and estimates on global losses due to insect pests has been put at about 30% of potential world food, fibre and feed production (NRI, 1992).

In Nigeria, considerable economic losses due to insect pests have been reported. For instance, the pod sucking bugs (PSBs) that infest cowpeas have been estimated to destroy about 10-89% of the pods in unsprayed cowpeas (Booker, 1965). Raheja (1976) and Singh and Allen (1979) observed that losses in fodder and grain yields attributable to insect pests of cowpeas ranged from 20% to almost 100%. Olatunde and Soaga (1999) evaluated the deterioration caused by *Callosobruchus maculatus* on cowpeas, *Vigna unguiculata* and observed an average weight loss of 35.2% or an average loss of 4.6% per insect. The percentage weight loss of 35.2% was more than that recorded by Singh and Jackai (1985) but within the range of 20% and 100% recorded on stored cowpea seeds by Gibbon and Pain (1988). Losses due to this insect have been estimated to exceed $US30 million annually (Caswell, 1973). Yield losses of 60-100% caused by the insect pest complex were reported on okra (Anonymous, 1986) while an estimation of about 50% qualitative and quantitative losses in dried fish has also been reported (Odeyemi *et al.,* 2000).

Mosquito-borne diseases constitute a major health problem in the world. The WHO statistics in 2010 showed that malaria accounts for about 300,000 deaths from over 20 million clinical attacks annually. In a study carried out on mosquito breeding sites in Obafemi Owode Local Government Area of Ogun State, Nigeria (Amusan, *et. al*., 2004), the three main species of mosquitoes encountered namely *Anopheles gambiae*, *Aedes aegypti* and *Mansonia africana*, were important vectors of malaria, yellow fever and filariasis respectively (Gillet, 1872; Maxwel, *et. al.*, 1990; Robert *et. al.*, 1992). Similar studies carried out in rice plantation communities in Ogun State showed the presence of *An. gambiae, An. funestus, Ae. aegypti* and *Culex quinquefasciatus* which are proven vectors of malaria and/or bancroftian filariasis in Africa (Amusan, *et. al.,* 2005).

Apart from malaria, other mosquito-borne diseases have also accounted for huge economic losses and low productivity in many parts of the Africa mostly in rural communities. Trypanosomiasis which is transmitted by tsetse flies (*Glossina* species) constitutes serious threat to human and ruminant animals in many cattle rearing communities of Africa where the disease causes high mortality and morbidity to the affected hosts. Recent studies on blackflies (*Simulium damnosum* complex) in some farming communities in Ogun and Oyo States reported over 40% loss in human productivity due to the incapacitation by onchocerciasis (river blindness) and biting nuisance of the insects (Adeleke *et al*., 2010a; 2011).

5. Man's Strategies/Intervention and My Research Contributions on Man/Insects struggle for dominance

Mr. Vice-Chancellor Sir, various techniques have been deployed by man to control the insect pests that attack him and his possessions. Besides the age-long conventional pesticide applications and intercropping/ crop rotation practices, other techniques as reviewed by various authors include sterile insect technique (Okhoya, 2003); medicinal plants and botanicals (Adedire *et. al.* 2006); host plant resistance (Olatunde *et al*., 2007); feeding deterrents and repellents (Bekele, *et. al*., 1996) and insect growth regulators (Akinwumi *et. al*., 2006). Over the last 22 years of my research life, I have worked on a number of these intervention strategies, particularly Host Plant Resistance, with significant contributions to knowledge and the evolution of strategies that are environmentally friendly and sustainable. Permit me, Mr. Vice-Chancellor, to dwell extensively on this strategy and some others that I have undertaken singly and jointly with other researchers in insect pest management.

Host Plant Resistance

Interest in plant resistance as a major component of integrated pest management of insects has increased significantly in the last 50 years (Davis, 1985), although the use of host plant resistance in insect control dates back to the late 1800's when domestic cultivars that inherently resist insect pests were studied (Wiseman, 1985). By the late 1920's only two scientific papers have been written on the general subject of plant resistance to insect (Mumford, 1931).

Snelling (1941) defined plant resistance as "those characters that enable a plant to avoid, tolerate or recover from attacks of insects under conditions that would more severely injure other plants of the same species". Painter (1951) defined resistance as "the relative amount of heritable qualities possessed by the plant which influence the ultimate degree of damage done by the insect in the field". Beck (1965) however restricted plant resistance to "the collective heritable characteristics by which a plant, species, race or individual may reduce the probability that an insect species, races, biotype or individual can successfully utilize the plant as a suitable host. Although Beck's definition restricts plant resistance to the successful use of a plant as a host by the insect, it excludes the plant's ability to recover or repair losses after injury has occurred.

Earlier classification of resistance in plants to insects included those of Mumford (1931) who classified resistance on two bases: 'epiphylaxis' which is related to external protection agencies and 'endophylaxis' which was used to describe the internal protection afforded by the biochemical qualities of the plant. Painter (1951) later classified plant resistance to insects into three broad categories: (i) non-preference (or antixenosis, Kogan and Ortman, 1978) which denotes the group of plant characters and insect responses that lead an insect away from a plant or plant part for oviposition, food, shelter or a combination of the three, (ii) antibiosis which included those adverse effects on the insect life history which results when a resistant host is used for food, and (iii) tolerance in which the plant shows an ability to grow and reproduce itself or to repair injury to a marked degree inspite of supporting a population of insects approximately equal to that damaging a susceptible cultivar. Resistance can also be classified by the degree of intensities: immunity, high, moderate and low resistance (Wiseman, 1985) or types: vertical or specific and horizontal or general (Gallun and Khush, 1980).

Of all these classifications, the most frequently used and generally accepted are those proposed by Painter (1951), that is, non-preference, antibiosis and tolerance. These three components result from independent genetic characters which are inter-related in their effects although the expression of genetic factors resulting in these mechanisms is frequently modified by various ecological conditions and other genes (Painter, 1951).

To demonstrate independently these components, specific experiments are usually delineated. Davis (1985) emphasized that carefully designed experiments must be carried out under choice and no-choice conditions for studying non-preference and antibiosis and under infested and uninfested conditions for tolerance to prove or disprove the involvement of each of the three components of resistance.

Criteria for measuring resistance is generally based on the effect that the insect has on the plant i.e. damage to various parts of the plant, plant survival, and yield and/or the effect that the plant has on the behavior and biology of the insect, i.e. effect on orientation, feeding, metabolic utilization of ingested food, growth, survival, egg-production and oviposition (Saxena, 1969). Several works have been reported on non-preference (Patnakamjoru and Pathak, 1967; Schoonhoven, *et. al.*, 1974); Sidhu, *et. al.*, 1979; Saxena and Khan, 1984) and antibiosis (Beck, 1950, 1956, 1957, 1960; Beck and Stauffer, 1957; Bottger and Patana, 1966; Maxwell, *et. al.*, 1967; Shaver and Lukefahr, 1969; Shaver, *et. al.*, 1970; Todd, *et. al.*, 1971; Maxwell and Jennings, 1980; Heinrichs and Rapusas, 1983; Khan and Saxena, 1985) in several agricultural crops. Similarly, a lot of work has also been reported on tolerance in several agricultural crops (Wilson and Davis, 1958; Howe and Pesho, 1960; Wood, 1961; Brett and Bastida, 1963; Dogger and Hanson, 1963; Chiang and Holdway, 1965; Doggett, *et. al.*, 1970; Zuber, *et. al.*, 1971; Wiseman, *et. al.*, 1972;

Schuster and Starks, 1973; Schweissing and Wilde, 1979; Morgan, *et. al*., 1980; Bishop *et. al*., 1982; Panda and Jeinrich, 1983; Sharman and Agarwal, 1984).

For cowpeas, non-preference (Perrin, 1977, 1978a; Akingbohungbe, *et. al*., 1980; Ezueh and Taylor, 1981), antibiosis (Perrin, 1978b; Singh, 1980;Ezueh, 1981; Ofuya and Akingbohungbe, 1986) and tolerance (Raman, 1980; Singh, 1980) have also been reported.

According to Wiseman (1985), a practical approach to plant resistance problem must locate the source of resistance and determine the level available. It must delineate the mechanism(s) of resistance involved, define the kind of non-preference or the degree and /or kind of antibiosis or tolerance in the resistant cultivars and establish if the resistance conferred is physical or chemical. It must also determine the associated factors to finally arrive at the bases of plant's resistance.

In a major research work undertaken by this speaker on identification of resistance in cowpea, *Vigna unguiculata* to the pod-sucking bug, *Clavigralla tomentosicollis*, this practical approach was adopted. Thirty-six cowpea cultivars evaluated in the screenhouse and in field experiments showed no absolute resistance in any of them, although cultivars with relatively low percentage seed damage were present (Olatunde, *et. al*., 1991a). Although only seven cultivars had less than 60% seed damage, yield components such as 100 seed weight and the number of pods per plant were related to the resistance of the test cultivars to the bug attack because cultivars with smaller seeds and more pods per plant were less damaged. However, the number of seeds per pod and morphological parameters of the cultivars were not related to the degree of seed damage (Olatunde, *et. al*., 1991a) (Table 3).

Further evaluation of the seven cowpea cultivars that had less than 60% seed damage for the mechanisms conferring resistance on them indicated that female bugs had no distinct ovipositional preference for any of the test cultivars used in the study although there was a distinct preference for egg laying on the undersurface of the leaves than on the other plant parts (Olatunde, *et. al*., 1991b). However, the test cultivars were less preferred for feeding by the bugs than the susceptible check, which suggests the presence of allelochemic substances or alternatively inadequate levels of kairomones to sufficiently incite feeding. The presence of true genetic resistance in the cultivars to *C. tomentosicollis* were confirmed by the lack of significant differences in percentage seed damage between the free-choice and no-choice test (Olatunde, *et. al*., 1991b).

Table 3: Percentage pod and seed damage and resistance index as recorded in a screen house evaluation of 36 cowpea cultivars subjected to artificial infestation of *C. tomentosicollis*[*, 1, 2]

Cultivars	%Seed damage	%Pod damage	Resistance index
TVu 3198	37.9 a	100.0 b	0.42 a
TVu 9062	39.4 ab	94.4 ab	0.43 ab
TVu 579	39.7 a-c	93.3 ab	0.44 ab
TVu 1890 (RC)	40.2 a-c	100.0 b	0.46 a-c
TVu 12664	41.9 a-c	90.9 ab	0.47 a-c
TVu 8687	42.0 a-b	88.6 ab	0.46 a-c
TVu 3372	43.2 a-e	92.6 ab	0.49 a-d
TVu 8525	43.9 a-e	100.0 b	0.50 a-d
TVu 1052	44.0 a-e	100.0 b	0.48 a-d
TVu 3199	44.0 a-e	95.6 ab	0.49 a-d
TVu 3355	44.4 a-e	100.0 b	0.49 a-d
TVu 230	45.4 a-e	100.0 a	0.51 a-d
TVu 3354	45.9 a-e	84.5 a	0.50 a-d
TVu 1030	50.5 a-f	100.0 b	0.56 a-e
TVu 3362	50.6 a-f	86.7 ab	0.56 a-e
TVu 3346	52.3 a-f	91.7 ab	0.58 a-e
TVu 3364	52.9 a-f	100.0 b	0.59 a-e
TVu 1 (RC)	54.2 a-f	100.0 b	0.61 a-f
TVu 1845	55.9 a-f	100.0 b	0.62 a-f
TVu 1159	58.0 a-g	90.9 ab	0.66 a-f
TVu 3368	64.3 a-h	100.0 b	0.71 a-g
TVu 1202	65.8 a-h	100.0 b	0.74 a-g
TVu 2952	66.1 a-h	100.0 b	0.75 a-g
TVu 1192	67.2 a-h	100.0 b	0.75 a-g
TVu 1271	70.4 a-h	100.0 b	0.78 a-g
TVu 1006	73.3 a-h	100.0 b	0.82 a-g
TVu 1166	74.0 a-h	100.0 b	0.83 a-g
TVu 1203	74.6 a-h	100.0 b	0.82 a-g
TVu 228	75.5 b-h	100.0 b	0.84 b-g
TVu 1841	76.6 b-h	100.0 b	0.84 b-g
TVu 1272	76.7 c-h	100.0 b	0.86 c-g
TVu 1068	79.2 d-h	100.0 b	0.88 d-g
TVu 2833	79.8 e-h	100.0 b	0.89 d-g
TVu 1153	85.6 f-h	100.0 b	0.96 e-g
Ife Brown (SC)	90.2 g-h	100.0 b	1.00 fg
TVu 1847	98.0 h	100.0 b	1.08 g

* Ratio of % seed damage in cultivars to % seed damage in the susceptible check.
1. Means followed by the same letter(s) in each column are not significantly different at the 5% level, based on Duncan's Multiple Test.
2. Values are means of three replications

The effects of the six cultivars on *C. tomentosicollis* showed that many possessed varying levels of antibiosis in the form of longer developmental periods of the nymphs, increased nymphal mortality, reduced weight of adult females and fecundity of mated females relative to the susceptible check (Olatunde and Odebiyi, 1991a). However, the fertility of the eggs and the longevity of female bugs appeared to be unaffected by the test cultivars, although female bugs reared on four of the cultivars, TVu 3354, TVu 3355, TVu 8525 and TVu 3364, laid fewer eggs than those reared on the susceptible check (Olatunde and Odebiyi, 1991a). This was probably due to the nutritional composition of these cultivars, as nutrition is probably the most important single factor that affects the fecundity of females (Engelmann, 1970).

Studies conducted to determine the relationship between the levels of infestation of *C. tomentosicollis* on three of the cowpea cultivars showed high damage threshold levels recorded on them (Olatunde, 2000) and this could be attributed to the combined antibiosis and antixenosis effects of the cultivars on the bug (Olatunde and Odebiyi, 1991a; Olatunde, *et. al.* 1991b) rather than tolerance because a plant that possesses only tolerance does not produce any adverse effect on insects to which it is tolerant (Kishaba and Mangliitz, 1965).

Besides determining the mechanisms of plant resistance to insects, identification of the bio-physical and biochemical basis of resistance is also important. Several experiments evaluating the role of biophysical and biochemical components in plant resistance to insect pests have been reported (Howe, 1949; Agarwal, 1969; Wallace, *et. al.*, 1973; Martin, *et. al.*, 1975; Gundlach and Chambliss, 1977; Chiang and Norris, 1983a, b). Olatunde and Odebiyi (1991b) evaluated the biochemical component of some cowpea seeds and varietal resistance to *C. tomentoscollis* and observed that varietal differences in the resistance of the cowpea cultivars are reflective of the concentration of some biochemical components of the test cultivars. Cultivars with high crude protein were positively correlated with the feeding preference of the bug on the cultivars, and supported faster developmental periods of the nymphs as well as higher egg production by females and vice-versa.

Inheritance studies involving TVu 3354, one of the cultivars found resistant to *C. tomentoscollis* in this studies gave broad-sense heritability estimates of 90.3% and 94.3% for the F2 and F3 generations respectively indicating that the cultivar, TVu 3354 has a level of resistance to *C. tomentoscollis* that is highly heritable and that can be incorporated into any of the already improved, well adapted, popularly accepted and high-yielding cowpea varieties to eliminate the need to spray against *C. tomentoscollis* attack on the plant (Olatunde, *et. al.,* 2007) (Table 4).

Similar research studies on host plant resistance were also undertaken, in conjunction with other researchers on other crops and insects of economic importance by this lecturer. For instance, studies on the variations in yield and susceptibility to insect attack in three varieties of roselle (*Hibiscus sabdariffa* var. *sabdariffa* L.) at different planting densities showed that susceptibility of roselle to insect attack was not significantly affected by NKP fertilisation although the dark red variety was particularly susceptible to insect attack, the densities of which were not affected by plant population densities and fertilizer application rate (Pitan, *et. al.*, 2007a).

Table 4. Weight gain, total development time and mortality of Clavigralla tomentosicollis nymphs on pods of susceptible (P_s) and resistance (P_R) cowpea parents and on their F_1 F_2 and F_3 generations

Cowpea population	No. of plants tested	Nymphal weight gain (mg)	Variance of weight gain	Nymphal development time (days)	Nymphal Mortality (%)
Ife Brown (P_s)	30	62.5^a	14.0	13.5^a	10.0^c
TVu 3354 (P_R)	30	31.2^c	5.7	15.0^a	86.7^a
F1 (P_s x P_R)	30	42.7^b	2.9	14.5^b	46.7^b
F_2	60	46.2^b	92.0	14.5^b	70.0^a
F_3	80	45.5^b	157.2	14.0^c	40.0^b

Means followed by the same letter in each column are not significantly different at $p < 0.05$

Also, the yield response of cowpea, *V. unguiculata*, to infestation of *Asperia armigera* showed that the capacity of *A. armigera* to cause significant cowpea yield loss was the same with other major pod-sucking bugs on cowpeas (Pitan, *et. al.*, 2007b).

In field evaluation of eighteen accessions of *Corchorus olitorius* for resistance to flea beetles, *Podagrica spp.*, infestation, five accessions, NHCo1, NHCo6, NHCo14, NHCo15 and NHCo21, showed significantly lower leaf damage and significantly higher yield compared to others tested (Pitan, *et. al.*, 2008).

Chemical Control

The use of insecticides in the control of insect pests dates back to the 19th century when DDT was discovered by Paul Muller to control mosquitoes. Since then there had been a massive use of these chemicals because of their effectiveness, especially against large pest populations, their fast action and their ease of availability. The chemical control of insects on crops has been reported by a number of workers (Taylor and Ezedinma, 1964; Booker, 1965; Swaine, 1969; Materu and Makusi, 1972; Metha and Nyiira, 1973; IITA, 1977; IITA, 1986; Amotobi, 1994, 1995; Kyamanywa, 1996; Okeleye and Ariyo, 2000). Olatunde and Olatunde (2004) recorded significantly lower number of insect pests and significantly higher fruit yields on okra from plots treated with Carbaryl and Cypermethrin compared with the control plots and the plot treated with wood ash, indicating that the synthetic insecticides were effective in the control of the insects on the crop. Oyekanmi, *et. al.* (2006) evaluated the effect of spraying regimes on insect pest incidence and grain yield on some released improved varieties of cowpeas and the yield advantages derivable if exposed to varied number of insecticide spray. The researchers observed significantly higher number of *Maruca vitrata* in the no spray regime relative to the 1, 2 and 3 spraying regimes while significantly higher yields were recorded on IT90K-277-2 under 3 sprays than when sprayed once.

However, the advantages conferred by the use of these compounds on insect pest control were not without its side effects. It is generally known that once an insect is removed from an ecosystem, a vacuum is created and the natural balance is disrupted and thus with increased pesticide usage, more problems developed. These include the resistant of the insects to pesticides which occurs when the applied pesticides kill off the susceptible individuals in the population leaving those with resistant genes to survive and multiply. Development of pesticides resistance has been recorded in over 500 insect species worldwide (Georghiou, 1990); pest resurgence, which is when the insecticides applied wipes off both the pests and natural enemies' populations thus allowing the pest population to bounce back faster than the natural enemies' population; secondary pest outbreak, which results from the killing of natural enemies of pest insects that were not pests in the first instance, thus allowing their populations to increase to pest proportions due to the absence of their natural enemies; pollution, when the applied pesticides pass well beyond their intended target and cause environmental disturbances and poisoning, which is when these pesticides are accidentally found in food and food products consumed by man, resulting in death or illness. In a research study that I participated in 2007, scientific investigations were conducted on pesticidal contamination of milk and milk products in Lagos State by analyzing a total of 240 samples of the products bought off the shelf at selected markets in the State using the AOAC method of milk extraction. Lindane was found in 7.5% of the samples while its isomers (B-HCH and G-HCH) accounted for 1.67% and 2.91% respectively. Heptachlor was detected in 3.3% of the overall samples while chlopyrifos occurred in 12.91% of the samples. Endosulphan and Aldrin were not detected at all (Ilori *et. al*., 2008). Although these pesticides were detected at low concentrations in all samples analyzed, 29.17% of the milk and milk products indicated the presence of these pesticide residues. With most government focusing on achieving food security through increased food production, and the illegal importation and use of these pesticides by individuals, there is the possibility of increased levels of the residues in food with the attendant threat to the health of the populace.

Intercropping

Intercropping is the simultaneous planting of two or more crops within sufficient spatial proximity to result in inter-specific competition and complementation in various forms (Anon., 1978). It is a common feature of tropical agro-ecosystems (Norman, 1974), particularly in the Nigerian subsistent farming system where the farmers mix one or more vegetables with most or all the other crops such as yams, maize, cassava, etc. This cropping system increases crop diversity, modifies the insect habitat and interferes with insect identification of, and response to its host plants (Tahvanainen and Root, 1972), and reduces insect pest incidence and damage relative to monocrops (Ofuya, 1991; Pitan and Odebiyi, 2001). Pitan and Olatunde (2006) investigated the effectiveness of tomato intercropped at different times with cowpea or okra in controlling the field densities of cowpea pod-sucking bugs and okra flea beetles. The authors recorded significantly lower densities of the pod-sucking bugs (*Clavigralla tomentosicollis, Riptortus dentipes, Anoplocnemis curvipes* and *Nezara viridula*) on cowpeas intercropped at 2 weeks after transplanting tomatoes than those obtained in the sole crop. Similarly, cowpea seed damage was significantly lower ($p<0.05$) on cowpea planted at 2 and 4 weeks after transplanting tomatoes than in the monocrop and when cowpea and tomato were planted simultaneously. In the tomato/okra intercrop, the number of flea beetles (*Podagrica* spp.) was significantly lower ($P<0.05$) in the intercrop than in the sole crop, irrespective of the time of intercropping. Damage was also significantly higher in the sole crop than in the intercrop while yield comparable to that of the monocrop was obtained at 2 weeks after transplanting. Similarly, Adetiloye, *et. al.* (2002) evaluated four cropping systems in the control of maize stem borers and the effects on maize growth and grain yield and reported that the presence of cowpea strips reduced the level of stem borer infestation compared to sole maize. The authors also indicated that the rotation of sole crop of late maize with early season sole cowpea plot was an important cultural control method for maize stem borer infestation.

Other Research Studies Undertaken

Apart from my research efforts on host-plant resistance, chemical control and intercropping as highlighted above, I have participated in other research studies in basic and applied entomology. I worked on the comparison of sampling time and technique for assessing pod sucking bugs population on cowpeas to fill the gaps on knowledge on the relative efficiency of the different sampling methods used for pod sucking bugs on this crop. Although the result of this study indicated that relatively reliable estimates of pod sucking bugs population on cowpea could be achieved if sampling was done between 7 am and 9.30 am using the direct count method and at 7 am using the drop cloth method, the direct count of the bugs on the cowpea was considered ideal and recommended since neither the insects nor their hosts are destroyed, and since the direct count is easy to undertake and sampling could be done single-handedly (Olatunde and Odebiyi, 1991c).

I have equally participated in many insect vectors related studies. I co-joined in research studies on the determination of breeding sites of larval mosquitoes in Abeokuta, Ogun State (Mafiana, *et. al*., 1998), in the relative abundance of mosquito larvae breeding in ground pools and artificial containers in Ajana, Ogun State (Amusan, *et. al*., 2004), in the sampling of mosquitoes with CDC light trap in rice field and plantation communities in Ogun State (Amusan, *et. al*., 2005), on the perception on onchocerciasis vectors around Osun River, Southwestern Nigeria (Adeleke, *et. al*., 2011a), on bioecology of *Simulium damnosum* complex along Osun River, Southwestern Nigeria (Adeleke, *et. al.,* 2011b), in investigating the biting behavior of *S. damnosum* complex and *Onchocerca volvulus* infection along the Osun River, Southwest Nigeria (Adeleke, *et. al*., 2010c), in morphotaxonomic studies on *S. damnosum* complex along Osun River, Southwestern Nigeria (Adeleke, *et. al*., 2010d) and in the molecular characterization of the *S. damnosum* complex found along the Osun River system, in South- western Nigeria (Adeleke, *et. al.,* 2010e). These research studies are novel. For instance, our research studies on breeding sites of mosquito larvae in Abeokuta, Ogun State presented the first record on mosquito fauna in the capital city of Ogun State (Mafiana, *et. al.*, 1998) while that on molecular characterization of *S. damnosum* complex along Osun River System provided the first account of molecular profile of *S. soubrense* Beffa in literature and also served as impetus for further studies towards reviewing the taxonomic status of this species (Adeleke *et al*., 2011b). Our just concluded results on mosquito vectors in Osogbo is the first of its kind as no information exist on mosquito fauna in the metropolis.

I worked with my colleagues on Morphometrics and enzyme activities in the femoral muscles of variegated grasshopper, *Zonocerus variegatus*, (Orthoptera: Pyrgomorphidae) during post-embryonic development (Ademolu, *et. al.*, 2009), in the nutritional value assessment of variegated grasshopper, *Z. variegatus*, (Orthoptera: Pyrgomorphidae) during post-embryonic development (Ademolu, *et. al.*, 2010a) and in studies to examine the trend in the number and types of hemocytes in all the developmental stages of *Z. variegatus*, (Orthoptera: Pyrgomorphidae) during post-embryonic development (Ademolu, *et. al.*, 2010b).

I also participated on pollution research studies with colleagues on the effect of lead pollution on the performance and protein content of two soybean varieties (Soyingbe *et. al.,* 2007), on the physico-chemical characterization of leechates generated from simulated leaching of refuse from selected waste dumps in Abeokuta city, Nigeria (Bamgbose *et. al.*, 2007) and on pesticide residues in milk and milk products in Lagos, Nigeria. *(Ilori et al., 2008)*

6. Conclusion

In this lecture, I have taken this august audience through the interaction that exists between man and insects. I have also x-rayed the efforts of man in subjugating these six-legged animals through the use of various strategies and approaches. The unending struggle between man and insects that attack him and his possessions started even before the commencement of civilization and despite man's utilization of numerous advances against these insect pests, he has not succeeded in eradicating any but in damaging his environment and causing more problems. Initial efforts by Man to subdue these six-legged creatures were intended to reduce the insect pest population to zero. These have proved virtually impossible because the insects kept responding to the onslaught of man through various survival strategies. Current efforts are now geared towards ensuring that these insect pests are not completely eliminated but their negative effects reduced to the barest minimum. Host Plant Resistance and Intercropping are two of the many methods of insect pest management that have been used by this lecturer as alternatives to insecticides. Other sustainable and environmentally friendly methods that have been used by researchers also include use of attractants (e.g. pheromones) and repellents, sterile insect release systems, trap crop barriers and biological control. I have concentrated my research efforts in Host Plant Resistance because of its self-renewing nature, its suitability to low-input farming and the ease of its use in the development of integrated pest management. Host-Plant Resistance studies should be integrated with other methods of control with a view to exploring the possibility of cohabiting with these six-legged creatures and living harmoniously with them. After all they were the first occupiers of the earth and Man's landlord.

It is therefore imperative that Man must live in harmony with insects, cultivate those positive values that they confer on him and his possessions and restrict them from their destructive impacts through the utilization of strategies that will keep their negative aspects in check.

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