NONTOXIC APPROACHES TO INSECT CONTROL

Dr. Quraishi inspects a vial of one of the non-toxic chemicals being investigated for insect control. Technician Kathleen Lee assists in the background.

M. S. Quraishi

INTRODUCTION

Man's concern for his environment is not new. Hamlet, after calling air ". . . this most excellent canopy . . .", ruefully added, ". . . why it appears no other thing to me than a foul and pestilent congregation of vapors".

We appreciate the misgivings of Hamlet and feel that the sanctity of the environment is of national interest; but of equal importance to our national well-being are the present high standards and yields of our crops. Pesticides when used properly do not appreciably affect the former, but provide a tremendous enhancement in both the quality and quantity of the latter. However, insecticides in use today have some inherent drawbacks; they are almost all toxic to life, and it is this quality which is undesirable.

Dr. Quraishi is professor, Department of Entomology.

To overcome this poisonous aspect of pesticides, efforts are being made in several laboratories, including our own, to develop non-toxic substances which will in some way keep insects under check and yet produce the minimal effect on man and his environment. We are taking full advantage of the knowledge that has accumulated concerning each insect.

EVOLUTION OF INSECTS AND VERTEBRATES

All living organisms, about two billion years ago, made their debut from common roots and therefore share some common vital principles. For that reason, insecticides which kill insects by disrupting basic biochemical processes can also adversely affect other living organisms including man.

However, as the tree of life grew, its sprouts developed into branches with characteristics of their own. Thus, about half a billion years ago two separate buds, among the many sprouts, began to grow into two of the most important groups of animals, namely the arthropods, insects and their allies, and the vertebrates, the animals possessing backbones. As these separate branches started growing and burgeoning, their offspring started on divergent paths of evolution. Let us consider some of the major specialities acquired by the arthropods and the vertebrates.

Skeleton — To support their body the arthropods developed an external skeleton, known as exoskeleton, composed mostly of cuticle. With each spurt of growth the exoskeleton had to be shed and replaced, a process known as molting. The vertebrates, however, developed an internal skeleton of bones which keeps pace with the growing body.

Growth and Maturation — Since development and procreation are essential to life, both groups developed proficient systems for controlling growth and maturity by internal secretions called hormones. But each group developed its own types of hormones and an entirely different system of controls.

Communications — The need to transmit information became obligatory as sexual reproduction and, later on, identity of character and community developed. Here again the two groups developed different secretions, and different means for this purpose. By the very nature of their origin these secretions had to be highly specific. For it would have been chaotic had the sex attractant of one female species attracted males of several species. In insects, secretions which influence the behavior of other members of the same species are known as pheromones.

Metamorphosis — One of the distinctive features of insects is that they are almost always hatched in a condition morphologically different from that of the adult. In order to achieve the latter, they have to pass through changes of form which are collectively termed metamorphosis. In some insects which form the pupa, these changes are drastic. This type of metamorphosis does not have a parallel in the higher forms of life.

QUEST FOR NEW MEANS OF CONTROL

In our search for selective or non-toxic insecticides, these divergencies in evolution are being exploited to their full extent, and we will consider each difference separately.

Ecdysone

The change of skeleton or molting is controlled by an insect hormone called ecdysone whose structure was announced in 1965. It was synthesized in 1966. Related compounds have also been isolated with ecdysone, but we will use the word ecdysone loosely to include all related compounds. Ecdysone causes molting in all insects upon which it has been tested. It is therefore possible that ecdysone can be used to propel insect molting out of phase and thereby kill the insect.

Ecdysones from Plants

During the past three years, great interest has been aroused in certain plant groups which contain chemicals related to or identical with ecdysone. Possibly the plants utilize these for protection against insects and related organisms. The rhizomes of the common fern **Polypodium vulgare** contain one per cent ecdysterone on a dry weight basis.

In our own laboratory we have been investigating local plant extracts and have discovered several extracts which accelerate molting. All these compounds, if prudently investigated, can provide the basis for non-toxic control of arthropods.

Insect Teratogens

Since the insect cuticle is different from the vertebrate covering, we have been studying chemicals which would produce premature hardening or structural defects in cuticle. We have found relatively non-toxic substances which have the desired effect on developing insect cuticle. Ecdysone also has a similar effect. Here again we have substances which can throw insect development out of sequence without being **per se** toxic.

The main advantages in using this approach will be the non-toxicity of the materials used and the rapidity of their degradation in the environment. One of the major disadvantages in utilizing the above approach is the universality of the action of these substances on all forms of arthropods. Their extensive use may result in indiscriminate mortality of arthropods.

Hormones, Growth and Maturation

Development in both insects and vertebrates is controlled by hormones. However, hormones called gonadotropins determine vertebrate maturation. In insects the juvenile condition is promoted by the presence of juvenile hormone which prevents cells from maturing. This juvenile hormone is therefore a remarkable substance. Though its structure was deciphered in 1967, even before its isolation in pure form and identification, several chemically different compounds with juvenile hormone activity had been detected in animals and plants, and the list of substances which mimic this hormone is increasing.

Chemicals like these again can be utilized for control by creating an imbalance in the sequence of events in insect development. Though most of these chemicals affect a wide variety of species, some are species-specific. This specificity opens up the possibility of achieving control of target species without adversely affecting other arthropods in nature.

We have also discovered in our laboratories that several local plant extracts inordinately prolong the larval stage of mosquitoes, and further investigations on identification of the active principles are in progress.

During the summers of 1971 and 1972 we plan to conduct field investigations on promising plant materials.

Chemical Language of Insects

The chemicals of communication — pheromones — have been a subject of intensive study during the last decade and considerable progress has been made in identifying or isolating in sufficiently pure form a number of these substances, including sex attractants, warning and aggregating substances. These chemicals can be used in various ways. Sex attractants can be used to attract a large number of males into "death traps" or to baits where they are "sterilized", treated with special chemicals or pathogenic organisms and released again in the population to spread the chemical or pathogen to the females they mate with.

The atmosphere can be permeated with pheromones thereby throwing the males into complete confusion. Warning pheromones could be applied to the items we want to protect. Aggregating pheromones could be used to bring together a large number of insects and then utilizing them for the destruction of their own kind as discussed above for males.

Metamorphosis

In many insects, during metamorphosis the larval tissue is largely or almost completely destroyed and the adult tissue which replaces it is developed from certain masses of formative cells. This development is unparalleled in vertebrates, and consequently the biochemical processes involved appear to be different from those found in higher forms of life. Therefore substances which are "innocuous" to the larval or adult stage and yet can disrupt metamorphosis are of special interest to us. A synthetic insect pheromone — the "Queen Substance" — was first reported to possess this type of specific "toxicity" synchronized with pupal metamorphosis by the present author and a co-worker in 1965. Since then a search among plants has revealed the presence of substances which appear to be "innocuous" to the larvae of mosquitoes, but the pupae formed from treated larvae do not live to be adults.

Ecdysone has been reported to be toxic to larvae of mosquitoes, but we have found that at certain dose levels it also manifests its toxic action only during metamorphosis in mosquitoes.

Substances with restricted lethal action synchronized with metamorphosis thus provide another avenue for exploration. They may either be suppressing some vital biochemical change or throwing into confusion the orderly sequence of events necessary for the transition from larval to adult stage.

OTHER AVENUES OF INTEREST

Sterile Male Technique for Insect Control

In the case of some insects, satisfactory control and even eradication is possible by using "sterile" males which can effectively fulfill the mating desires of the females in a given population without successfully fertilizing them. The basis of this sterility is actually dominant lethal mutations induced by either ionizing radiations (X-rays or gamma rays) or chemicals. Males thus treated are released in large numbers in a population to overwhelm the normal male population and effectively compete for the limited number of females present. Some conditions greatly favor control by this technique, and these include the innocuousness of the male, so that there are no potential hazards involved in releasing a large number of insects in the population; and restricted mating by the female. Best results are obtained if the female mates only once. This assures the elimination of all potentials of reproduction by a female which has mated once with the sterile male. Eradication of screw worm fly from a few states has been achieved with the use of this technique.

Genetic Control

1. Hybrid Sterility. In the previous example, release of males with induced lethal mutations was discussed. Similar control can be obtained by selecting from nature strains which are incompatible, or by manipulating genetic mechanisms already existing in nature. For instance, some allopatric species (similar species geographically separated) mate readily when brought together but yield few offspring which are usually all sterile.

2. Deleterious Genes. Insects carrying deleterious genes could be introduced into a natural population. Genes affecting sex ratio, especially those which produce a preponderance of males in species where only the female is noxious (e.g., mosquitoes), are useful.