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A REVIEW OF METHODS OF CONTROLLING ARTHROPOD PESTS OF SANITARY AND VETERINARY IMPORTANCE

WIESŁAW SOBÓTKA[1] and BOGUMIŁA STYCZYŃSKA[2]

[1] Institute of Organic Chemistry, Polish Academy of Sciences, Warsaw
[2] State Institute of Hygiene, Warsaw

In the past five years (1980 - 1984), nothing sensational has come to light as regards techniques of combatting noxious insects, arachnids or ticks, especially those of medical or veterinary importance.

As in the integrated methods applied in agriculture to limit the populations of arthropod pests [8], arthropods that imperil humans and animals are controlled largely by chemical means, although the practical possibilities of applying biological and other methods of control are still being examined [2, 4, 15].

One assumes that the search for new biorational chemical products, while most likely based on the achievements of biotechnology, will nevertheless require a more intimate knowledge of the biochemical and physiological processes of arthropods. Quite possibly, biotechnology and genetic engineering will make it possible to enhance the activity of such microbiological agents as *Bacillus thuringiensis* or avermectin-type "agri cultural antibiotics", or of other fermentation products which are toxic towards arthropods.

The elucidation of certain processes in the metamorphosis of insects and in the functioning of their nervous systems has borne practical fruit: juvenoids-modified insect juvenile hormones [19], which disturb the insect's endocrine processes without harming the environment — have now been added to the armoury used against mosquitoes, flies that develop in cattle excrement, fleas and Pharaoh's ants. Continued research into the anti-hormonal action of naturally-occurring compounds led to the discovery of the anti-ecdyson activity of azadirachtin, the well-known insect deterrent isolated from *Azadirachta indica*.

New information from the spheres of insect neurophysiology and endocrinology has clarified somewhat the role of neurohormones in neurotransmission and in the regulation of metabolic changes. The co-transmission and neuro-hormonal functions of proctolin, the low-molecular-weight neuropeptide of arthropods, which contains five amino acids, are currently being scrutinised.

Work done in Poland by D. Konopińska, J. Bogusławska-Jaworska and W. Sobótka, respectively of the University of Wrocław, Wrocław Medical Academy and the Institute of Organic Chemistry of the Polish Academy of Sciences in Warsaw, has shown that proctolin, an invertebrate neurohormone, is also effective in certain processes in vertebrates, for example, the restoration of phagocytosis by PMN leukocytes in children suffering from leukaemia [5]. Attempts to use proctolin to inhibit the life processes of insects have not met with the success expected of them because the substance penetrates the cuticule only with difficulty and, even if it does so, it is rapidly decomposed by proteolytic enzymes.

The arsenal of modern methods of controlling harmful arthropods has been supplemented by non-lethal chemical compounds, chiefly of natural origin, which modify the insect's behaviour. These compounds have engendered considerable interest because they are selective, species-specific and need to be applied in only small doses. They include pheromones.

Examples of insect pheromones that are of sanitary importance are faranal and monomorine produced by Pharaoh's ants and sex pheromones of the German cockroach *Blattella germanica*. Pheromones have also been found in ticks, including those from the family *Ixodidae*. Ticks use pheromones for intraspecific communication when assembling, aggregating and attaching themselves to a host. The last-mentioned reaction is provoked by volatile compounds, one of which has been identified as o-nitrophenol.

Ecdysteroids, hormones known to be present in insects and crustaceans when they metamorphose, have been shown to occur in the various stages of development in ticks, especially *Ixodide*.

Some ecdysteroids caused the salivary glands to degenerate in specimens of the tick species *Amblyomma hebraeum* (*Acari*: *Ixodidae*), while juvenile hormones and ecdyson affected vitelogenesis.

At present, the application of organic chemical compounds is the most efficient way of dealing with harmful arthropods, including those of sanitary importance. Pyrethroids [12] play an important part here and are replacing organophosphorus and carbamate insecticides. One of the most effective photostable pyrethroids is deltamethrin [16]: it is highly toxic against arthropods and does not pollute the environment.

Permethrin is another pyrethroid commonly used to control house flies. But in a number of European countries, these insects are becoming increasingly resistant to this compound. Accordingly, there have appeared new insecticides with a so-called propyrethroid action for combatting cockroaches, and others which are stereoisomeric pyrethroids based on chrysanthemic acid. These latter go by the name of d-prallethrin or d-cyphenothrin and are recommended for use in the home against mosquitoes and cockroaches. They "flush" the cockroaches out of the nooks and crannies in which they conceal themselves on to open spaces where they come into contact with lethal doses of pyrethroid. This ensures efficient extermination. Similar effects have been achieved using pyrethroid inclusion compounds with β-cyclodextrin.

The search for pyrethroid synergists with a low toxicity towards vertebrates revealed that some juvenoids, e. g. RO 135223, fulfil this requirement in preparations used to kill *Musca domestica vicina*.

There has been an upsurge of interest shown in the already well known group of amidine acaricides sold under the trade names of Amitraz and Chlordimeform. These cause ticks to detach themselves from their hosts, and inhibit egg-laying; they are lethal towards the larvae of the cattle tick *Boophilus microplus* (Canestrini).

A new class of insecticides of natural origin are the avermectines, which have a macrolide disaccharide structure and are recovered from the fermentation broth of the soil microorganisms *Streptomyces avermitilis*. Unlike organophosphorus and carbamate insecticides, avermectine B moderates the way in which GABA controls chloride ion conductivity at synapses. Avermectines are also effective against some insect species which are resistant to the conventional insecticides and acaricides — this again is evidence for a different mechanism of action. However, avermectines are not likely to be widely applied against arthropods because they are highly toxic towards mammals.

Five of the eleven communications submitted to this Symposium concern chemical methods of controlling arthropods of medical or veterinary importance. Three deal with the practical aspects of carbamate, pyrethroid and organophosphorus insecticides.

Racewicz [17] studied the sensitivity of cockroaches *Blattella germanica* (L.) from Polish merchant ships to three carbamate insecticides — Propoxur, Dioxacarb and Carbaryl. The cockroaches were least sensitive towards Carbaryl.

Ramisz et al. [18] found that the pyrethroid preparation Butox, whose active constituent is deltamethrin, was highly efficient in combatting ectoparasites of animals at the Warsaw Zoological Garden. Butox was most effective against fleas (*Ctenocephaloides* ssp.) and lice (*Linognathus* ssp.), though less effective against itch-mites (*Notoëdres cati*). The proprietary product K-Othrin, containing an emulsion of deltamethrin, was used to control fleas and other insects in the animals enviroment.

Kroczyński et al. [6] showed that a mixture of an organophosphorus insecticide with photostable pyrethroids is more effective than any of the individual constituents of the mixture. Filter paper saturated with a mixture of bromfenvifos and deltamethrin, cypermethrin or permethrin remained toxic towards house flies and the nymphs of the Oriental cockroach (*B. orientalis* L.) for three months.

The results of studies on chitin biosynthesis inhibitors and on juvenoids (Cycloprene) are contained in two reports.

Styczyńska et al. [20] described the effect of diflubenzuron administered in food to cockroaches (*Blattella germanica* L.), house flies and Pharaoh's ants. Diflubenzuron was lethal against house flies, and rendered female cockroaches infertile, but was ineffective against Pharaoh's ants.

Maciejewska [10] assessed the effect of the Polish experimental juvenoid Cycloprene on the metamorphosis of the flea *Xenopsylla cheopsis* (Rutks). She found that, depending on the concentrations applied to third stage larvae, the emergence of adult insects is impaired, the treated larvae perish, or there appear anchimeric developmental forms, possessing both larval and pupal features, which are incapable of survival.

Information on mechanical methods of controlling insects of sanitary importance is provided in two communications. Novotná [13] describes the construction of emergence traps for catching *Culicoides* in southern Bohemia. Coch [3] proposes the use of electric light traps in enclosed spaces for controlling synanthropic wasps (*Para vespula*) and flies (*Calliphoridae*, and some *Muscidae*). Two types of traps have received official approval in the GDR and are already in use.

The development of non-chemical methods of combatting insects noxious from the sanitary point of view was put forward by the WHO already in 1970. In 1982, the WHO Committee of Experts on Biology and Disease Carrier Control reported on the state of research into pest management by biological methods [1], and recommended that future research programmes should take the following into consideration:

— bacteria: *Bacillus thuringiensis* serotype H14, *Bacillus sphaericus*,

— fungi: *Culicinomyces clavosporus, Legenidium giganteum, Tolypocladium cylindrosporum* and some *Coelomomyces* ssp.;

— nematodes: a number of *Mermithidae* ssp., including *Romanomermis culicivorax, Romanomermis iyengari* and *Octomyomermis muspratti*;

— fish: local species should be studied as far as possible. Furthermore, *Oryzias latipes* could be a biological agent used against pests in permanent water bodies, while other species such as *Nothobranchius* spp. could be used in temporary water bodies.

The most useful of the foregoing organisms appear to be those from the *Bacillus thuringiensis* and *Bacillus sphaericus* groups, which produce spores and stable, highly active toxins. These toxins are powerful larvicides acting exclusively through the alimentary tract and are chiefly used against *Diptera*. They do not affect eggs, pupae or adult insects. Such selective action allows these bacteria to be used with safety in the human environment, generally for plant protection.

The *B. thuringiensis* serotype H14 is particularly effective against the larvae of *Aedes* and *Culex* mosquitoes and *Simulidae* ssp. of gnats.

The *Bacillus sphaericus* toxin is present on the surface of the spores. It is more effective than the *B. thuringiensis* toxin against certain mosquitoes like the *Culicini*. *B. sphaericus* can grow saprophytically in polluted water, unlike *B. thuringiensis* which is more active in clean water. Both species die in chlorinated water, although the toxin remains active and kills larvae which are carried into such water bodies by the current.

During malaria vector (mosquito) controls in cities, a strain of *Bacillus sphaericus* (H-26) was isolated from infected *Anopheles* larvae which causes 100% mortality in larvae of *Anopheles culicifacies*. It was also found that dead *Aedes aegypti* (L.) larvae improve the efficiency of the H-14 serotype of *B. thuringiensis* distributed in microcapsules by raising the mortality rate to 99%.

The fungi employed in the biological struggle belong to the classes *Chytridiomycetes*, *Oomycetes*, *Zygomycetes* and *Deuteromycetes* (Fungi imperfecti). *Coelomomyces* and *Coelomycidium* fungi are obligatory parasites of mosquito larvae. *Coelomomyces* fungi may be of particular importance for they frequently cause epizooties in larval populations which reduces their numbers by about 90%. Specimens from the genus *Simulium* are often attacked by these fungi too. It has been found that the fungi *Lagenidium giganteum* (*Oomycetes*), saprophytes preferring substrates containing chitin, are capable of attacking many *Aedes* and *Culex* species. This fungus produces zoospores on strongly sclerotised areas of the insect's cuticule.

Attention has also been drawn to another fungus, *Tolypocladium cylindrosporum* (Fungi imperfecti) which attacks mosquito larvae developing in brackish waters.

Nematodes, especially from the families *Mermithidae* and *Steinernematidae*, are potential insect parasites. *Mermithidae* ssp. are obligatory parasites — they must spend part of their development cycle inside a living host. A lot of attention is currently being devoted to three species: *Romanomernis culicivorax*, *Romanomernis iyengari* and *Octomyomernis muspratti*. *R. culicivorax* can reduce a population of mosquito larvae by 70 - 90%.

Neoaplectana nematodes from the family *Steinernematidae*, easily bred in vivo or in vitro, contain symbiotic bacteria in their alimentary tracts.

Nuclear polyhedrosis and cytoplasmatic polyhedrosis are pathogenic viruses attacking insects. Some 600 viruses have been isolated from agricultural pests but only a few from sanitary pests. The nuclear polyhedrosis virus shows promise: insects attacked by it perish rapidly. However, the low infection rate and virulence of viruses towards sanitary pests must restrict their usefulness against such insects.

Fish are one of the more important factors controlling mosquitoes under natural conditions. The chief reasons why fish have been chosen to act as larvivores are: a) their preference for a diet of mosquito larvae, b) small body dimensions (less than 6 cm long) which facilitates colonization, c) a high tolerance of salinity and pollution, and d) they are inoffensive towards other fauna in the aquatic ecosystem. *Oryzias*, for example, satisfies many of these conditions.

Some success has been achieved recently in the biological management of agricultural pest populations. The methods used against these insects include many insectivorous predators, parasitoids, some nematodes, *Bacillus popiliae*, *Bacillus thuringiensis* (3 variants), 3 registered *Baculovirus polyhedroses* (and 10 others which show promise), and 3 *Microsporidia* species. Some species of pathogens are also being studied for their usefulness against sanitary pests.

One pathogen, common to both agricultural and sanitary pests, is *Bacillus thuringiensis*; the reports submitted to the Symposium are the best illustration of this.

The experiments of Lonc, Mazurkiewicz and Szewczuk [9] show that *B. thuringiensis* was effective against mallophagans in hens. Parasites exposed to a 10% solution of Dipel lived for only another 5 - 6 hours; if treated with a similar concentration of Bacilan, the mallophagans died within 8 - 9 hours. Thus, the mallophagans tested, *Menopon gallinae* (L.) and *Eomenacanthus stramineus* (Nisch), are sensitive to the action of a spora-crystal complex of both preparations.

Olejniček [14] used *B. thuringiensis* var. *Israelensis* against gnats and achieved 99% mortality in the larvae of *Prosimilium tomosvaryi*, *Eusimilium vernum* and *Odagnia ornata*.

The development of residual insecticides during the past 40 years has made it much easier to combat carriers, especially of malaria in tropical countries. However, the increasing resistance of insects, environmental pollution, and the high costs of the new generation of chemical insecticides have meant that pest control can no longer be carried out solely by chemical means.

According to the 5th report of the WHO's Committee of Experts on

Biology and Disease Carrier Control published in 1981, 51 *Anophelini* species, 42 *Culicini* ssp. and 41 species of other arthropods of medical and veterinary importance have become resistant to one or more insecticides.

A few species of mosquito are known to have shown behavioural resistance: they have altered their feeding and sheltering habits in such a way that they no longer come into full contact with the deposit of insecticide.

Multiple resistance of house flies to several different insecticides, e.g. organophosphorus compounds with cross-resistance to carabamates, has been confirmed in many countries.

In 1983 - 84, Krzemińska, Gliniewicz and Styczyńska [7] carried out a study on the resistance of house flies in Poland to lindane and malathion, frequently used in insect management in this country. Only in 3 voivodeships were lindane-resistant populations reported, but populations exhibiting increased tolerance to this compound were present in 9 voivodeships. Flies were resistant to malathion in 13 voivodeships — this is probably due to the widespread application of this insecticide in agriculture.

Insects, chiefly flies, in a number of European countries such as Denmark, Sweden and Germany are reported to have developed resistance to synthetic pyrethroids. Decreased sensitivity to pyrethroids has been shown by cockroaches in the Soviet Union.

Permethrin, deltamethrin and cypermethrin are the synthetic pyrethroids most often used by the Polish sanitary authorities.

Malinowski [11] investigated the development of resistance in flies to deltamethrin and their cross-resistance to other compounds by selecting sensitive strains of flies over 20 generations. He detected cross-resistance to all the photostable pyrethroids — permethrin, cypermethrin, phenvalerate — and also to methoxychlor and DDT. The flies were not resistant to lindane and propoxur, so these compounds were used alternately in order to delay the development of resistance in the insects to pyrethroids.

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Authors' address:
01-580 Warszawa, Krasińskiego 29/40

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PRZEGLĄD METOD ZWALCZANIA SZKODLIWYCH STAWONOGÓW O ZNACZENIU SANITARNYM I WETERYNARYJNYM

W. SOBÓTKA i B. STYCZYŃSKA

Przedstawiono aktualny stan badań w dziedzinie metod chemicznego i biologicznego zwalczania stawonogów szkodliwych dla człowieka i zwierząt. Stosowanie organicznych związków chemicznych stanowi obecnie jeszcze najskuteczniejszy sposób zwalczania stawonogów. Ważną rolę odgrywają pyretroidy wypierające w wielu przypadkach insektycydy fosforoorganiczne i karbaminiany. Zwrócono uwagę na strategię poszukiwania nowych środków chemicznych opartych na lepszym poznaniu procesów fizjologicznych i biochemicznych w organizmie stawonogów. Poznanie niektórych procesów metamorfozy przyczyniło się do stosowania juwenoidów w zwalczaniu komarów. Dalsze poszukiwania wśród związków pochodzenia naturalnego doprowadziły do odkrycia działania antyekdysonowego deterentu owadziego. Nowe fakty z zakresu neurofizjologii i endokrynologii owadów umożliwiły poznanie neurohormonów uczestniczących w procesie neurotransmisji. Szczególnym obiektem zainteresowania stała się proktolina. Nową klasą insektycydów pochodzenia naturalnego są awermektyny. Mechanizm działania awermektyny B polegający na moderowaniu regulacji przez GABA przewodnictwa jonu chlorkowego w synapsach, odróżnia ją pod tym względem od klasycznych insektycydów fosforoorganicznych i karbaminianowych. Jednakże z uwagi na silną toksyczność awermektyn dla ssaków, nie wydają się one stanowić perspektywicznego środka zwalczania stawonogów. Alternatywne w stosunku do chemicznych metod zwalczania szkodliwych owadów są metody biologiczne, którym dalsze kierunki wytyczył Komitet Ekspertów Światowej Organizacji Zdrowia, uwzględniając takie czynniki biologiczne jak bakterie, grzyby, nicienie, ryby. Obiecującym patogenem zarówno dla szkodników rolnych, jak i sanitarnych okazał się *Bacillus thuringiensis*.

Mimo szerokiego, ekonomicznie uzasadnionego stosowania obecnie środków konwencjonalnych, wymienione zarówno nowoczesne grupy chemicznych środków zwalczania szkodliwych stawonogów, jak i patogeny, wytyczają perspektywiczne tendencje badawcze prowadzące w przyszłości do zbieżności metod dotychczas dzielonych na biologiczne i chemiczne. W przeglądzie uwzględniono również prace nadesłane na Sympozjum.