

SYNTHETIC PYRETHROID INSECTICIDES AND THEIR POTENTIAL USE IN SRI LANKA

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ABSTRACT

The merits and demerits of using synthetic pyrethroid insecticides in the control of agricultural pests are reviewed. While recognizing the favourable qualities of this group of insecticides the chief disadvantages, namely, resurgence and resistance, are adduced for recommending a very tight restriction on the use of this group in Sri Lanka.

INTRODUCTION

Considerable interest has been shown in our country in recent times on a group of compounds called synthetic pyrethroids. Ever since the insecticidal properties of natural pyrethrins were recognized, continuing studies seeking pyrethroids of synthetic origin have enabled the synthesis of insecticides with improvements over the natural pyrethrins. Pyrethrins were first discovered around 1800 in the Transcaucasus-Northern Iran region of Asia. It was first manufactured around 1828 in Dalmatia, Yugoslavia, and came to be used all over the world. Japan became the leading producer during World War I, followed by Kenya. Pyrethrin contents of *Chrysanthemum carneum*, *C. coccineum*, *C. cinerariaefolium* range from 1.3—3.0% in the flower heads (Metcalf, 1955).

Pyrethrins are highly toxic to a wide spectrum of insects; very safe for mammals (Table 1); highly unstable on exposure to light, air and moisture; easily destroyed by heat, light and alkaline hydrolysis. Pyrethroids were synthesized by improving, mainly the photostability of the compounds by replacing the photolabile groups in the molecule by other photostable groups (Roussel-Uclaf, 1982). Incorporation of antioxidants and ultraviolet filters improve their stability. Pyrethrins and pyrethroids are contact poisons, with quick knockdown effect; but without stomach or systemic action. Their primary site of action is the central nervous system by interfering with axonal transmission of nerve impulses.

If this group of insecticides has such merits, the question we have to answer is: Why do we not make good use of them? Why is it that the Sri Lanka Department of Agriculture has recommended them against pests of only two crops? These insecticides do possess good features; may be even better than the conventional groups like the chlorinated hydrocarbons, organophosphates and carbamates. Herve (1985) reported that within seven years of commercialisation of the first synthetic pyrethroid this group had come to occupy 20—25% of the world foliar insecticide market.

EFFECT ON NON-TARGET ORGANISMS

Synthetic pyrethroids are highly toxic to insects. Their insecticidal activity is four or five times higher than that of the other classes of insecticides. For instance, LD₅₀ of synthetic pyrethroids for insects is, on an average, about 0.5 mg/kg, whereas for organophosphates it is 2, chlorinated hydrocarbons 2.6, and carbamates 2.8 (Elliott, 1977). For instance, permethrin is said to be 10 to 15-fold more toxic than methyl parathion to the tobacco budworm (Twine and Reynolds, 1980).

Not only do they kill the pest insect but also other insects in the ecosystem. Pyrethroids are well documented to be toxic to parasites and predators of pest insects. They are also highly toxic to honey bees, fish and other aquatic fauna; but not very toxic to birds (Roussel-Uclaf, 1982; Hill, 1985).

PEST RESURGENCE

Destruction of the natural enemies of crop pests could lead to a pest population much higher than to begin with. This kind of resurgence of the pest has been sufficiently researched and documented in the case of the rice brown plant hopper (BPH). Extensive research was conducted at the International Rice Research Institute, Philippines (IRRI, 1977; 1978). It was found that synthetic pyrethroids, such as deltamethrin, cypermethrin and fenvalerate caused resurgence in BPH. It was shown that resurgence ratio of BPH for pyrethroids was 16.4 compared to other conventional pesticides. Resurgence was found to be due to:

- * increased fecundity,
- * increased feeding,
- * increased adult longevity,
- * shortened nymphal duration, and
- * killing of key predators (e. g. *Cyrtorhinus*, *Microvelia*, etc.)

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These effects were more pronounced when sublethal doses were used. Certain aspects of these tests were duplicated at the Central Agricultural Research Institute, Gannoruwa, and they confirmed that resurgence does occur with sublethal doses of decamethrin, alfoxylate and cypermethrin (Anonymous, 1982).

This resurgence phenomenon is not confined to rice. There are several recent reports from all over the world on the toxic effects of synthetic pyrethroids on the natural enemies of pests of cotton, grain legumes, vegetables and fruit trees. Predators such as the green lace wing, *Chrysopa* spp., and coccinellid ladybird beetles are reported to be very susceptible to these insecticides. So are parasites like *Trichogramma* spp. and *Tetrastichus* sp. of the cereal leaf beetle (Chari and Patel, 1983).

The problem of resurgence is more acute in the case of pests with sucking mouthparts—aphids, mites, mealy bugs, etc. Here we recall the fact that pyrethroids are non-systemic and are not very effective on these pests. Hence when the insecticide is applied to a crop the natural enemies are relatively easily killed but the pest is spared. This results in a population explosion, or a "man-made epidemic". Such was the experience in the case of the European red mite, *Panonychus ulmi*, on apple (Hall, 1979; Hyot *et al.*, 1978). Another report from Czechoslovakia too cites resurgence in a mite, *Tetranychus urticae*, due to permethrin, cypermethrin, deltamethrin and bioresmethrin (Hurkova, 1984). Sublethal concentrations of all these pyrethroids caused increased rate of oviposition in treated female mites. Such events have been reported on cotton from India, i.e. increased population levels of aphids, mites, and other sucking pests, following the application of synthetic pyrethroids (Chari and Patel, 1983).

RESISTANCE AND CROSS RESISTANCE

The phenomenon of resistance and cross-resistance is not restricted to synthetic pyrethroids. Cases of resistance among insects and mites to pesticides have been recorded to be about 430 as of the end of 1980 (Table 2). Out of this, 22 species or 5% have developed resistance to pyrethroids. This compares with 230 or 53% for DDT, 270 or 63% for cyclodienes*, 200 or 47% for organophosphates, and 51 or 12% for carbamates (Metcalf, 1984). There have been several new species added to

* Cyclodienes — synthetic cyclic hydrocarbons such as chlordane, heptachlor, aldrin, dieldrin, endosulfan, etc.

this list. The new number is 447 as of October, 1984 (Dr. G. P. Georghiou, pers. comm). The figure of 5% may lull one to think that this group is less prone to the development of resistance. Here we should remember that synthetic pyrethroids are of very recent origin (Table 3), and that they have been in wide use only since 1976. That is, for a group of insecticides that has been in large scale use for the past ten years only, this magnitude of resistance is something to take serious note of. Metcalf (1984) proposed a term "doubling time" as a measure of the rate of development of resistance. That is the number of years taken for resistance species to double their numbers, say, from 5 to 10; 10 to 20; etc. And, according to his calculation synthetic pyrethroids have the shortest average doubling time of 1 year, compared to 6.3 years for DDT (Table 4). Another index of resistance development was computed by Georghiou (1983), who reported a 7-fold increase of number of species resistant to pyrethroids between the years 1970 and 1980. The corresponding figure for cyclodienes is 2, DDT 2.34, organophosphates 3.7, and carbamates 17.

Several cases of pyrethroid resistance were found recently in diamond-back moth, DBM, *Plutella xylostella*, in Taiwan. Although pyrethroids had been introduced only in 1976, by about 1980 high levels of resistance appeared in most field strains. The resistance ratio* varied from 80 to 700 depending on the specific pyrethroid (Table 5). Resistance to pyrethroids has been reported on the green peach aphid (*Myzus persicae*) from Australia (Attia and Hamilton, 1978); *Heliothis* sp. on cotton from Australia (Gunning *et al.*, 1984), Egypt (Riskallah *et al.*, 1983) and USA (Crowder *et al.*, 1979); diamondback moth from Malaysia (Sudderuddin and Kok, 1978); and BPH from Japan (Ozaki and Kassai, 1984). The information from Singapore gives the highest level (37,000) of resistance (Table 6). (The many instances of resistance recorded in insects of medical and veterinary interests are not listed here).

A question may arise at this juncture: How did this happen, if this group of insecticides have been in use only for a short period of time? The majority of the documented evidence is upto about 1980—1981. Surprisingly there is a report that documents a 14-fold resistance in a strain of tobacco budworm (*Heliothis virescens*) in Australia even prior to the

* Resistance ratio = LD_{50} of resistant strain $\div$ LD_{50} of susceptible strain.

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commercial use of the insecticides (Twine and Reynolds, 1980). Similarly with aphid *Myzus persicae*, also in Australia (Attia and Hamilton, 1978). This illustrates the phenomenon of cross-resistance.

Early research on resistance to pyrethrins repeatedly pointed out the close relationship between resistance to DDT and resistance to pyrethrins. This kind of resistance, termed knockdown resistance or *kdr*, is believed to be governed by a recessive gene in the housefly and mosquito. This *kdr* gene is thought to lower the sensitivity of the nerve towards DDT. Flies that are homozygous to *kdr* and resistant to DDT are very likely to be selected for pyrethroid resistance.

Out of the 18 cases of cross-resistance between pyrethroids and other insecticides, there are 12 cases of cross-resistance to DDT. The following insecticides also have been implicated in cross-resistance: methyl parathion, dimethoate, malathion, fenitrothion, acephate, diazinon, chlorpyrifos, naled, chlofenvinfos, etc. Cross-resistance is a factor to beware. In Sri Lanka we have been using a wide variety of insecticides for pest control in agriculture. DDT was used very widely in the "1950s" & "1960s" both in agriculture and public health. Therefore, it is very that a large number of insect pests have developed resistance to DDT. A good example is the DBM on cabbage. DDT was found to be effective in 1954. 1958 the insect was found to be resistant to DDT (Anonymous, 1958). Endrin was recommended against it. Though DDT has not been recommended (and possibly not used) over the past two decades, the recessive *kdr* gene may be presumed to be present in the pest population.

"Once selected for, resistant genes have virtually limitless persistence in the wild insect population. Although the gene frequency of the resistant allele may decrease upon removal of the specific insecticide pressure, it is ever present, so that the resistant strain becomes dominant as soon as selection pressure is reapplied" (Metcalf, 1980; 1984).

This happened with the housefly in Denmark (Keiding, 1977). The resistant gene had persisted for more than 20 years, during which time no DDT was used. Resistance surfaced within two months of reapplication of the insecticide. If such was the case, what would happen if pyrethroids are used extensively and intensively? We would be selecting the same *kdr* gene, thereby all pyrethroids would become ineffective over a short period of time; including any new pyrethroid to be synthesized with the same mode of action (Shono, 1985; Valiulis, 1985).

It is to be hoped that we learn from the experiences of other countries, and avert such crises in Sri Lanka. A Thai scientist reported that synthetic pyrethroids were approved for control of the cotton bollworm by the Thailand Government in 1976, and the farmers rapidly accepted them. These chemicals are of low human toxicity, highly effective and cheap (because of their low dosage), so that the farmers generally used them for the entire season. In just a few years many farmers throughout the country complained about the lack of effectiveness. This was experimentally supported: resistant bollworms had built up rapidly in all pyrethroid treated plots by 1979 (Wangboonkong, 1981). He predicted that if the trend continued that group of compounds would cease to be used. The same sequence of events took place in Thailand on the onion caterpillar, *Spodoptera exigua*. A similar experience was reported with *Spodoptera* on shallot in Sri Lanka in the 1970s.

After reporting a 700-fold resistance to pyrethroids in DBM, two Malaysian scientists wondered what the future of pyrethroids on the control programme of DBM in the Cameron Highlands of Malaysia would be. Their prognosis was that given the severe cross-resistance present in the highland strain of *Plutella xylostella* and the massive and regular use of a variety of insecticides, without any possibility of relent as far as one could foresee, the future was bleak (Sudderuddin and Kok, 1978). The same could be said of the central highlands and other intensive vegetable producing areas of Sri Lanka.

CONCLUSION

The inherent qualities of pyrethroids as insecticides are so favourable that they would approach the ideal, if not for resurgence and resistance. There is presently a great pressure to introduce these insecticides into various crop

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protection situations in Sri Lanka. But the proper use of pyrethroids entails ultra-judicious management. As already discussed resistance develops quite rapidly, and entomologists are generally agreed that these valuable insecticides must be used with discretion so as to extend their useful lifespan. This can be done by avoiding routine application, and by incorporating it in an integrated pest control programme (Elliott *et al.*, 1978; Miller, 1985; Valiulis, 1985). These insecticides should be reserved for use as a last line of defence only when other conventional insecticides have failed.

**"PYRETHROIDS ARE PRECIOUS; THEIR BENEFITS MAY BE SO EASILY CURTAILED
BY WANTON APPLICATION."** (Adapted from Southwood, 1976).

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Table 1. Toxicities of classes of insecticides to mammals and insects.^(a)

<i>Class</i>	<i>Rat</i> ^(b) (mg / kg)	<i>Insect</i> ^(c) (mg / kg)	<i>Ratio</i> (column 2 ÷ 3)	<i>Av. dose</i> ^(d) (kg / ha)
Carbamate	45 (15)	2.8 (27)	16	0.7 (12)
Organophosphate	67 (83)	2.0 (50)	33	0.6 (45)
Organochlorine	230 (21)	2.6 (26)	91	0.5 — 3.0
Pyrethroid	2000 (11)	0.05 (35)	4500	0.01 — 0.2

a. Elliott, 1977, except column 5; number of data items in brackets.

b. From published acute oral LD₅₀ values.

c. From published values, principally to 4 species.

d. Roussel-Uclaf, 1982.

Table 2. Number of documented instances of insect resistance to insecticides (Metcalf, 1984).

<i>Insecticide group</i>	<i>Number of species</i>	<i>Percent of total*</i>
Cyclodienes	270	63
DDT	230	53
Organophosphates	200	47
Carbamates	51	12
Pyrethroids	22	5
Total	430	

* The percentages add up to more than 100 as many insect species are resistant to more than one group of insecticides.

Table 3. Discovery of synthetic pyrethroids

<i>Insecticide</i>	<i>Year</i>
1. Allethrin	1949
2. Tetramethrin	1965
3. Bioallethrin	1967
4. Resmethrin	1967
5. Fenvalerate	1972
6. Permethrin	1973
7. Deltamethrin	1974
8. Decamethrin	1975
9. Cypermethrin	1975
10. Cyfluthrin	1976
11. Fluvalinate	1981
12. Flucythrinate	?

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Table 4. Approximate rate of development of resistance to insecticides (Metcalf, 1984).

<i>Number of resistant pests</i>	<i>DDT</i>	<i>Cyclodienes</i>	<i>Organo- phosphates</i>	<i>Carbamates</i>	<i>Pyrethroids</i>
5	1951	1954	1959	1971	1976
10	1952	1955	1962	1972	1979
20	1955	1956	1964	1974	1980
40	1960	1959	1968	1977	—
80	1968	1965	1972	—	—
160	1974	1971	1976	—	—
Average doubling time (yr.)	6.3	5.0	4.0	2.5	1

Table 5. Resistant ratios of a resistant strain of DBM to several synthetic pyrethroids in Taiwan (Llu *et al.*, 1981).

<i>Insecticide</i>	<i>Resistance Ratio</i>
Permethrin	77.6
Cypermethrin	316.4
Decamethrin	714.3
Fenvalerate	710.5

Table 6. Development of resistance to synthetic pyrethroids in *Plutella xylostella* in Singapore (Ho *et al.*, 1983).

<i>Insecticides</i>	<i>Resistance Ratio</i>
Deltamethrin	1,600
Cypermethrin	37,000