OVERVIEW OF PESTICIDE RESISTANCE PROBLEMS IN SOUTHEAST ASIA

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When synthetic organic pesticides were first introduced, they provided an effective measure for plant protection. However, this now faces serious problems as a result of the development of pesticide resistance in insects, pathogens, weeds, and vertebrates. Although the resistance of insects to insecticides has a history of more than 70 years, serious repercussions have been observed only during the last 40 years, following the extensive use of synthetic organic insecticides such as DDT, BHC, and parathion. At least 447 species of insects and mites, 100 species of plant pathogens, 48 species of weeds, 2 species of nematodes, and one mammal (the rat) have developed resistance to pesticides. Other than American, European and Far Eastern countries, pesticide resistance problems are now known to occur in Southeast Asian countries as well. The diamondback moth, the brown planthopper, the rice stemborers, aphids, mosquitos, and stored grain pests have developed pesticide resistance in Southeast Asian countries.

Development of resistance to pesticides in an organism is an evolutionary process and a universal phenomenon throughout the extensive range of organisms known to be pests. The definition of resistance given by the World Health Organization is: "The development of ability in a strain of insects to tolerate doses of toxicants which would prove lethal to the majority of individuals in a normal population of the same species". There are many concepts and suggestions for measures to overcome resistance in pests. However, strategies to avoid or delay the development of resistance in target pests are also needed. In this paper, I will review the development of future tactics and discuss the obstacles to their development in Southeast Asia.

STATUS OF RESISTANCE

Available records, including institutional reports and private communications, indicate that at least 13 species of insects have developed resistance to insecticides in Southeast Asian countries (Appendix I).

During a symposium on the Major Insect Pests of the Rice Plant held at the International Rice Research Institute (IRRI) in the Philippines during September 1964, many entomologists from Southeast Asian countries reported on their work in major rice insect pests (IRRI 1964). It was recorded that the brown planthopper *Nilaparvata lugens* had become a rice pest; however, this insect was not important except in localized places in the Philippines. The introduction of the new high-yielding rice varieties, which were highly fertilizer-responsive and lacked pest resistance genes, resulted in increased pest attacks, especially by the brown planthopper. This in turn required increased pesticide applications.

Resistance problems in rice plant pests are found in the brown planthopper (Morallo-Rejesus & Bernardo 1973) and the green rice leafhopper *Nephotettix cincticeps*, which have both developed high levels of resistance and multiple resistance. The brown planthopper migrates for long distances between Southeast Asian countries, and also to Japan. Brown planthopper insecticide resistance in Japan depends primarily on the resistance level of immigrants (Nagata & Mochida 1986), with the consequence that this becomes not only a domestic problem but also an international one.

The most serious pesticide resistance problem in Southeast Asia is that of the diamondback moth, *Plutella xylostella*. This insect has become a limiting factor on the production of crucifers in the Philippines (Magallona 1986) and is also known to be a problem in Indonesia, Malaysia, Thailand, and Taiwan (Cheng et al. 1984, Sun et al. 1978). Teh et al. (1982) have stated that unfortunately, the present situation with regard to control programs of insect pests in general, especially in the Cameron Highlands, holds little hope for the future.

Grain protection from stored product insects is one of the major problems in both small farms and large warehouses (Lim 1974). Malathion is commonly recommended for sack and seed treatment and several insects have developed resistance to malathion.

FUTURE TACTICS

Georghiou and Taylor (1986) classified the factors influencing selection of resistance into three categories - genetics of resistance, biology/ecology of the pest, and the control operations used. The first two categories are beyond the operator's control, but knowledge of their contribution serves to enable an assessment of 'resistance risk'. The last category is under the direct control of the operator, and can be altered to any extent necessary and feasible depending on the risk of resistance that is revealed by the genetic and biological factors.

The commonly adopted tactics against pesticide resistance are: increase in the dosage of pesticides; introduction of alternative pesticides which have no cross resistance; and usage of synergists (Barroga & Morallo-Rejesus 1975-76, Cheng et al. 1983, 1985, Liu et al. 1982, Mochida & Basilio 1983). Table 1 shows the diamondback moth situation, with insecticides treatment histories, in the Cameron Highlands area of Malaysia. Under prevailing chemical control measures used by farmers in the Cameron Highlands, pesticide resistance has continued to be a problem and there appears to be no solution in sight.

Due to the difficulty of developing new pesticides (Morallo-Rejesus 1985) efforts to practice sound insect control, such as selective insecticide use (Feng & Wang 1984, Mani & Krishnamoorthy 1984, Sivapragasam et al. 1986) to retard the development of pesticide resistance are needed. For this purpose, selection pressure should be reduced, and the prediction and immediate recognition of pesticide resistance are important. Because biological and operational factors

Table 1. Some of the insecticides used in the Cameron Highlands, Malaysia, against *P. xylostella*, since the early 1960s (Sudderuddin & Pooi-Fong 1978, modified).

Plutella situations[a]	OB	OB	OB	OB	HI	OB	HI	HI	HI	HI	HI	HI	HI	HI
INSECTICIDE	1964	65	66	67	68	69	70	71	72	73	74	75	76	77
DDT	+													
Dimethoate	+	+	+	+	+	+	+	+	+	+				
Malathion	+	+	+	+	+	+	+	+	+	+				
BHC	+	+	+	+	+	+	+	+	+	+				
Diazinon	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Trichlorphon		+	+	+	+									
Dimethoate			+	+	+	+	+	+	+	+				
Dichlorvos				+	+									
Methomyl	+	+											+	+
DDT+malathion					+	+	+	+	+	+				
Methamidophos (Tamaron 50%)							+	+	+	+	+	+	+	+
Methamidophos (Monitor 50%)									+	+				
Cartap										+	+	+	+	+
Resmethrin												+	+	+
Triazophos												+	+	+
Fenvalerate													+	+
Prothiophos											+	+	+	+
Watathion®													+	+
Chlordimeform HCL														+

[a] OB = Outbreak, HI = High incidence.

influence the rate of development of resistance in a pest, and the genetic factors may also differ, local differences in resistance must be considered (see Figure 1).

The most accurate way to monitor resistance is through bioassay, and many relevant methods, such as topical application, dipping and spraying, have been reported in the literature. Such procedures are useful in determining resistance levels in the laboratory (Cheng 1981). However, large numbers of specimens and prolonged testing are required to obtain significant results, which even then can be ambiguous, especially when the resistance is real and the population is heterogeneous. Simple biochemical tests for resistance have been proposed for detecting organophosphate and carbamate resistance in populations of the brown planthopper and the green rice leafhopper (Miyata & Saito 1984). By these methods, individual insects of the population can be monitored in preliminary field surveys. Recently a network project, FAO/IRRI/12 for Southeast Asian countries, was initiated to monitor the susceptibility levels of rice pests such as the brown planthopper, leaffolder and green rice leafhopper.

Table 2 shows the results of studies on the mechanisms of resistance to insecticides in the diamondback moth. We have some tactics to delay the development of phenthoate and fenvalerate resistance in the diamondback moth.

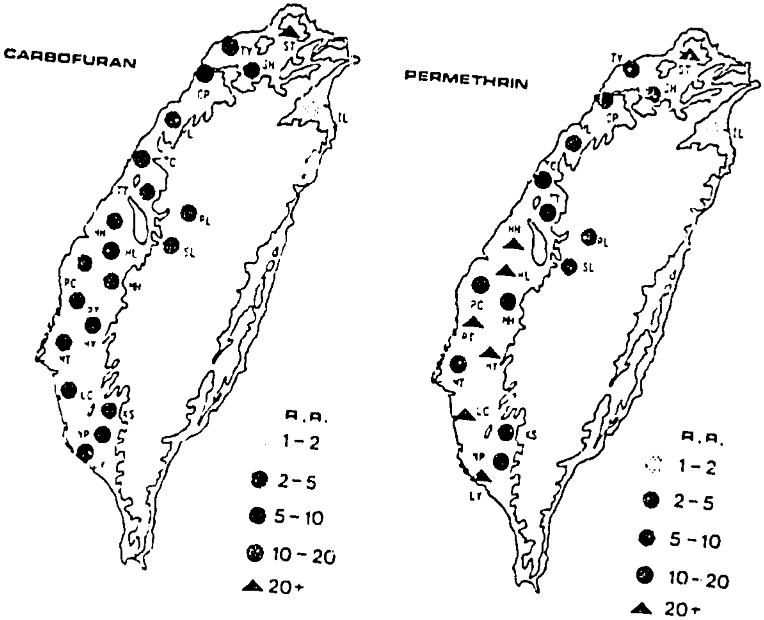

Figure 1. The geographic distribution of resistance in *P. xylostella* in Taiwan, 1980–1981 (Cheng 1981, modified)

Table 2. The mode of resistance to insecticides in *P. xylostella* (Noppun et al. 1983, 1984, 1986, 1987).

Phenthoate resistance	Fenvalerate resistance
Reduced cuticular penetration	Reduced cuticular penetration
Increased metabolism	Increased metabolism
Insensitive AChE	
High cross resistance to prothiophos, cyanophos and methomyl	Cross resistance to phenthoate, prothiophos, cyanophos, and methomyl
Low cross resistance to dichlorvos and cartap	
No cross resistance to acephate and fenvalerate	No cross resistance to cartap
Synergism to TPP	Synergism to TPP and PB
Unstable resistance?	Unstable resistance?

The alternating use of insecticides and the combination of synergists appear to be effective in delaying the development of resistance.

One additional important tactic on resistance management, apart from IPM, is forecasting of the pest population density. The light trap and the pheromone trap are expensive. A yellow sticky trap for the diamondback moth could be used for forecasting adult population density in the field (Sivapragasam & Saito 1986). However, even if the above tactics are available, their adaptation to farm practices and acceptance by extension persons or farmers have to be determined (Saito 1975).

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APPENDIX I

Cases of field resistance to insecticides in Southeast Asia.

Insect	Insecticide	Location	Source
Rice insect pest			
Nilaparvata lugens	Monocrotophos	Bay, Philippines	Morallo-Rejesus and Bernardo 1973
	Parathion X13 BPMC X4	Taichung, Taiwan	Ku et al. 1976
	MTMC X19	Mat Chandu, Malaysia	Heong 1983
	Chlorpyrifos+ BPMC Acephate	IRRI, Philippines	Mochida and Basilio 1983
Nephotettix cincticeps	Fenthion X 7 Fenitrothion X13	Iri, Korea	Lee and Yoo 1975
	BPMC X64 Carbaryl X11 Malathion X80 Methyl parathion X680	Taichung, Taiwan (1975)	Ku et al. 1976
	BPMC X92 Carbaryl X16 Malathion X97 Methyl parathion X748	Taichung, Taiwan (1976)	Ku and Wang 1975
	Malathion X9 Dimethoate X6	Jiuxin, Thejian	Chen et al. 1978
Laodelphax striatellus	Malathion X27	Jinjo, Korea	Choi et al. 1975
Inazuma dorsalis	DDT	Taiwan	Ma 1965[a]
Chilo suppressalis	Fenthion X3	Yong In, Korea	Kim et al. 1970
	Fenthion X6 Fenitrothion X3	Joan, Korea	Lee and Yoo 1975
Tryporyza incertulas	∂-BHC X7 Parathion X3	Chin Shan, Shanghai	Res. Group on Resistance 1977
	Parathion	Taiwan	Ma 1965[a]
Leptocorisa acuta	BHC, cyclodiens OP	Thailand	Chakrabandhu 1965[a]
Leptocorisa varicornis	Methoxychrol, BHC, Cyclodiens	Thailand	Chakrabandhu 1965[a]
Scotinophara lurida	BHC, cyclodiens	Taiwan	Ma 1965[a]

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APPENDIX I *continued*

Insect	Insecticide	Location	Source
Vegetable insect pest			
Plutella xylostella	DDT	Lembang, Indonesia	Ankersmit 1953
	Methyl parathion X288-1753	College, Daet, Ligao, Bugies, Atok, Guinobatan, Philippines	Barroga and Morallo-Rejesus 1975-1976
	Malathion X18-822		
	DDT X10-397		
	Dichlorvos X15-172		
	Diazinon X15-172		
	Malathion X2096	Cameron Highland, Malaysia	Suddcruddin and Pooi-Fong 1978
	Chlorpyrifos-Methyl X620		
	DDT X530		
	∂-BHC X64		
	Dichlorvos X40		
	Cartap X16		
	Methomyl X12		
	Methamidophos X6		
	Carbaryl X6		
	Resmethrin X5		
	Fenvalerate X5		
	Malathion X11	Lu-Zhon, Taiwan	Lee and Lee 1979
	Diazinon X8		
	Dichlorvos X13		
	Mevinphos X9		
	Phenthoate X16	Cong-Shan, Taiwan	
	Endosulfan X9	Lu-Zhon, Taiwan	
	Carbofuran X33	Sheh-Tzu, Taiwan	Cheng 1981
	Mevinphos X11	Lu-Chu, Taiwan	
	Cartap X4	Shui-Li, Taiwan	
	Permethrin X75	Hsi-Hu, Taiwan	
	Fenvalerate X75	Lin-Yuan, Taiwan	
	Malathion X3650	Ban-Chau, Taiwan	Liu et al. 1982
	Diazinon X413		
	Dichlorvos X300		
	Permethrin X110		
	Fenvalerate X2880		
	Cartap X199		
	etc.		
	Permethrin X754	Cameron Highland, Malaysia	Teh et al. 1982

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APPENDIX I *continued*

Insect	Insecticide	Location	Source
Stored product insect			
Sitophilus zeamais	Lindane	Alor Star, Penang, Malaysia	Lim 1974
Rhyzopertha domonica	Lindane	Alor Star, Malaysia	Lim 1974
Tribolium castaneum	Malathion, lindane	Alor Star,Batu Caves,Kuala Lumpur, Penang, Malaysia	Lim 1974
	Malathion	Jatibarang, Cianjur, Semarang, Irian Jaya, Sumatra Selatan, Indonesia	Osman and Morallo-Rejesus 1981

[a]Data from Metcalf 1984.