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Note

Cross Resistance Patterns in Malathion- and Fenitrothion-Resistant Strains of the Rice Brown Planthopper, *Nilaparvata lugens* Stål

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The malathion- and fenitrothion-resistant (Rm and Rf) strains of the rice brown planthopper were established by successive selection with malathion and fenitrothion, respectively. The Rm strain selected with malathion for 42 generations developed 93-fold resistance to malathion, and the Rf strain selected with fenitrothion for 39 generations developed 289-fold resistance to fenitrothion. The Rm strain showed 5- to 26-fold cross resistance to naled, tetrachlorvinphos, monocrotophos, propaphos, fenthion, fenitrothion, diazinon, isoxathion, pyridaphenthion, disulfoton, dimethoate, phenthoate, mecarbam, carbaryl, propoxur, XMC and methomyl. The Rf strain showed high resistance to fenthion (271-fold), diazinon (71-fold), isoxathion (270-fold), pyridaphenthion (412-fold), EPN (177-fold), malathion (421-fold) and phenthoate (157-fold), and also showed 5- to 32-fold cross resistance to naled, dimethylvinphos, tetrachlorvinphos, monocrotophos, propaphos, disulfoton, dimethoate, mecarbam, carbaryl, MPMC, BPMC, propoxur, XMC and methomyl. In both Rm and Rf strains, no cross resistance to trichlorfon, pyrethrins and organophosphorus fungicides such as IBP and edifenphos were found.

INTRODUCTION

The rice brown planthopper, *Nilaparvata lugens* Stål has recently developed multiple resistance to organophosphorus and carbamate insecticides.[1–3] The control of resistant planthopper has become one of the main strategics in the rice production in Japan. It is of urgent necessity to discover insecticides which are effective against resistant strains of the rice brown planthopper. In the present study, the malathion- and fenitrothion-resistant (Rm and Rf) strains of the rice brown planthopper were established by successive selections with malathion and fenitrothion in the laboratory, and cross resistance patterns in both strains were examined.

MATERIALS AND METHODS

A population of rice brown planthopper was collected in the field in Ouchi of Kagawa Prefecture in September 1975, and it was described as 0 population by Ozaki and Kassai.[2] This population was selected with either malathion or fenitrothion as described by Okuma and Ozaki.[4] Malathion and fenitrothion were diluted with acetone to appropriate concentrations. A constant volume of this solution was dropped into a glass tube (1.1 cm in diameter and 10.4 cm in length) by a microsyringe, and then 50 μl of acetone was added to each tube in order to spread the insecticide uniformly on the inner surface of the tube. After acetone was evaporated completely, about 30 fourth- to fifth-instar larvae were placed into each tube, and were allowed to contact a thin film of insecticide at 25±1°C. When insect mortality reached about 70%, the insects were transferred into a glass container in which rice seedlings were placed. Final mortality was 70 to 75%. The survivors were reared on the rice seedlings at 25±1°C under

16 hr illumination per day. Selection with malathion and fenitrothion was repeated for 42 and 39 generations, respectively. During the selection, the final mortality of each generation was maintained at 70 to 75% by regulating both the dose and duration of exposure to the insecticides. The selection had begun with about 5000 individuals for each insecticide. From the 2nd selection, about 2000 individuals were used.

LD_{50} values of 28 chemicals including organophosphates, carbamates, pyrethrins and organophosphorus fungicides were determined using the topical application method. The chemicals to be tested were diluted with acetone to each appropriate concentration, and each solution was topically applied at 0.25 μl per insect to the abdomen of female adults 3 to 5 days after emergence. The treated insects were given rice seedlings and they were kept at 25±1°C. Mortality was recorded 24 hr after application.

RESULTS AND DISCUSSION

LD_{50} values of various chemicals in the Rm and Rf strains of the rice brown planthopper was shown in Table 1 in comparison with those of the susceptible strain which has been

Table 1 LD_{50} values and resistance level to organophosphorus and carbamate insecticides, pyrethrins and organophosphorus fungicides in susceptible (LE), Rm and Rf strains.

Chemical tested	LE[a)]	Rm		Rf	
	LD_{50}[b)]	LD_{50}	R.L.[c)]	LD_{50}	R.L.
Naled	6.40	43.4	6.8	85.6	13.4
Dimethylvinphos	2.47	10.5	4.3	35.7	14.5
Tetrachlorvinphos	3.40	26.0	7.6	47.4	13.9
Monocrotophos	0.80	7.61	9.5	15.3	19.1
Propaphos	2.59	13.6	5.3	43.9	16.9
Fenthion	4.63	118	25.5	1256	271
Fenitrothion	10.8	104	9.6	3118	289
Diazinon	10.0	128	12.8	706	70.6
Isoxathion	15.9	137	8.6	4295	270
Pyridaphenthion	4.52	29.3	6.5	1866	413
EPN	52.2	236	4.5	9259	177
Disulfoton	6.19	78.4	12.7	196	31.7
Malathion	9.37	870	92.8	3944	421
Dimethoate	11.6	71.0	6.1	145	12.5
Phenthoate	15.2	381	25.1	2393	157
Mecarbam	4.08	54.1	13.3	66.2	16.2
Trichlorfon	154	323	2.1	260	1.7
Carbaryl	0.85	4.18	4.9	10.1	11.9
MTMC	2.41	6.37	2.6	9.82	4.1
MPMC	2.07	6.22	3.0	11.9	5.7
Isoprocarb	1.35	2.98	2.2	6.03	4.5
BPMC	1.61	4.60	2.9	8.07	5.0
Propoxur	0.27	1.40	5.2	3.21	11.9
XMC	1.60	15.4	9.6	24.3	15.2
Methomyl	0.58	7.29	12.6	10.1	17.4
Pyrethrins	2.02	2.73	1.4	4.12	2.0
IBP	724	734	1.0	881	1.2
Edifenphos	71.8	74.9	1.0	105	1.5

[a)] from Ozaki & Kassai,[2)] [b)] μg per gram of body weight, [c)] resistance level: LD_{50} in the resistant strains/LD_{50} in LE strain.

described as LE strain by Ozaki and Kassai.[2] The LD_{50} values of malathion in the Rm strain and of fenitrothion in the Rf strain were 93- and 289-times higher than those of the LE strain, respectively. The Rm and Rf strains were found as susceptible as the LE strain to trichlorfon, pyrethrins and organophosphorus fungicides such as IBP and edifenphos. The LD_{50} values of almost all carbamates and organophosphates obtained in the Rm and Rf strains were larger than those for the LE strain.

The Rm strain showed more than 10-fold cross resistance to monocrotophos, fenthion, fenitrothion, diazinon, disulfoton, phenthoate, mecarbam and methomyl, and 5- to 10-fold resistance was found to naled, tetrachlorvinphos, propaphos, isoxathion, pyridaphenthion, dimethoate, carbaryl, propoxur and XMC. This strain showed three- to five-fold resistance to dimethylvinphos, EPN, MTMC, MPMC and BPMC.

The Rf strain showed more than 70-fold cross resistance to fenthion, diazinon, isoxathion, pyridaphenthion, EPN, malathion and phenthoate, 12- to 32-fold resistance to naled, dimethylvinphos, tetrachlorvinphos, monocrotophos, propaphos, disulfoton, dimethoate, mecarbam, carbaryl, propoxure, XMC and methomyl, and up to five-fold to MPMC and BPMC. This strain showed three- to five-fold resistance to MTMC and isoprocarb. In both Rm and Rf strains, the resistance level to phosphate-type compounds among organophosphorus insecticides were lower than those to phosphorothionate- and phosphorothoate-type compounds.

The resistance level to fenitrothion and fenthion in the rice brown planthopper populations collected in fields in Kagawa Prefecture in 1975 and 1976 were higher than that to malathion.[2] In the present study, the Rm strain with 93-fold malathion resistance level, however, showed only 10- and 25-fold resistance to fenitrothion and fenthion, respectively. This suggests that the successive selection of the rice brown planthopper with malathion developed a specific factor(s) for malathion resistance, and this factor(s) did not cause cross resistance to another organophosphorus insecticides whose chemical structures were extremely different from malathion.

The Rf strain showed high cross resistance to many organophosphorus insecticides, and was more resistant to each organophosphorus insecticide than the Rm strain. Similar phenomenon was observed in the malathion- and fenitrothion-resistant (Rm and Rf) strains of the small brown planthopper, *Laodelphax striatellus* Fallén, which were successively selected with malathion and fenitrothion.[5] This implies that similar resistance mechanism exists in the Rm and Rf strains of two species of planthoppers.

The Rm and Rf strains of the rice brown planthopper also showed more than five-fold resistance to almost all carbamate insecticides. As the carbamate resistance level was low, before the repeated selection,[2] the resistance to carbamate should have been developed during the selection experiment with the organophosphorus insecticides.

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要　約

トビイロウンカのマラソンおよびフェニトロチオン抵抗性系統の殺虫剤に対する交差抵抗性

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1975 年 9 月に香川県の野外で採集したトビイロウンカ個体群を malathion と fenitrothion で連続淘汰し，malathion と fenitrothion 抵抗性 (Rm と Rf) 系統を確立した．malathion にて 42 世代淘汰した Rm 系統は malathion に 93 倍，fenitrothion にて 39 世代淘汰した Rf 系統は fenitrothion に 289 倍の抵抗性を示した．Rm 系統は naled, tetrachlorvinphos, monocrotophos, propaphos, fenthion, fenitrothion, diazinon, isoxathion, pyridaphenthion, disulfoton, dimethoate, phenthoate, mecarbam, carbaryl, propoxur, XMC と methomyl に 5 から 26 倍の範囲で交差抵抗性を示した．Rf 系統は fenthion, diazinon, isoxathion, pyrida-

phenthion, EPN, malathion と phenthoate に 70 倍以上の高レベル交差抵抗性を示し，naled, dimethylvinphos, tetrachlorvinphos, monoctrotophos, propaphos, disulfoton, dimethoate, mecarbam, carbaryl, MPMC, BPMC, propoxur, XMC と methomyl に 5 から 32 倍の範囲で交差抵抗性を示した．大多数の有機リン剤に対する Rf 系統の抵抗性レベルは Rm 系統より高かった．Rm と Rf 系統の trichlorfon, pyrethrins と有機リン系殺菌剤の IBP と edifenphos に対する感受性は感受性(LE)系統とほぼ同等であった．