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Original Article

Joint Action of Chlorfluazuron with Synergists and Insecticides in Chlorfluazuron-Susceptible and Resistant Strains of Diamondback Moth, *Plutella xylostella*

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The synergistic action of triphenyl phosphate (TPP) and piperonyl butoxicide (PB) on chlorfluazuron was studied in chlorfluazuron-susceptible and resistant larvae of diamondback moth, *Plutella xylostella* (L.). Synergistic ratios with TPP and PB were approximately 7 and 4, respectively, in two resistant strains, namely TL-resistant (TL-R) and BK-resistant (BK-R) strains. There was no synergism with TPP and PB in TL-susceptible (TL-S) strain, while there was up to 2-fold with TPP and 3-fold with PB in the BK-susceptible (BK-S) strain. From these results, it is likely that the enhanced degradation of chlorfluazuron by a TPP-sensitive enzyme system is responsible for chlorfluazuron resistance in diamondback moth. Teflubenzuron at a nontoxic level ($<LC_1$) synergized chlorfluazuron in the resistant strains but did not in the susceptible strains. This result suggests that teflubenzuron interferes with chlorfluazuron degradation enzyme. Binary mixtures of chlorfluazuron with either teflubenzuron or pyriproxyfen produced a clear potentiation, especially in the resistant strains. On the other hand, there was no detectable joint action with fenvalerate, phenthoate, or thiodicarb. Potentiation of chlorfluazuron by teflubenzuron and pyriproxyfen might be due to interference at the site of action and/or with the chlorfluazuron degradation enzyme by teflubenzuron and pyriproxyfen.

INTRODUCTION

Diamondback moth, *Plutella xylostella* (L.), is a cosmopolitan serious pests of crucifer crops. It causes severe crop damage in infested areas due to control failure caused by the development of insecticide resistance. This insect pest has developed very high levels of resistance and a wide range of multiple-resistance to almost all the conventional insecticides used for control. Recently, reports on the development of resistance to conventional insecticides, including BT formulations and insect growth regulators (IGRs) are increasing especially in South East Asian countries and the U.S.A.[1-5]

Unfortunately, it is becoming increasingly difficult to find new compounds which are safe and highly inseciticidal to overcome the problem of pest resistance to insecticides. Consequently, investigators are directing their efforts to improve the effectiveness of existing products. Practically, this is possible through two ways, first by the use of synergists and second by the use of insecticides mixtures which may delay or retard the development of resistance.[6,7]

The significance of synergism studies arises for two main reasons. The first is that synergists may be used as a rapid and reliable method to predict the enzyme system(s) responsible for insecticide degradation when the proper enzyme inhibitor is used.[6,8] The second is that there is a possibility of improving the performance of efficacy of insecticides,[9] and also lower insecticide doses might help to reduce the impact of insecticides to the environment. When insecticide mixtures show potentiation in their joint action and/or if they can retard or prevent the development of resistance, then application of these mixtures could be considered as a possible resistance management tool.

In this study, synergism and joint action of chlorfluazuron with other insecticides were investigated in chlorfluazuron-susceptible and resistant strains of diamondback moth.

MATERIALS AND METHODS

Insects

Two Thai strains of diamondback moth, Tup Luang (TL) and Bang Khae (BK), were used for this study. At

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the time of collection, these two strains were 400- to 3400-fold resistant to chlorfluazuron and 37,500- to 70,000-fold resistant to teflubenzuorn compared to a Japanese susceptible (OSS) strain (Sinchaisri *et al.*, unpublished data). These two stains were imported from Thailand after being reared in the laboratory for two years without any insecticidal selection pressure. At that time, their resistance ratio (RR) values were as low as 16–62 to chlorfluazuron and 10–18 to teflubenzuron comparing to the same OSS strain(Fahmy *et al.*, unpublished data). Subcolonies of the TL and BK strains were selected for chlorfluazuron resistance in the laboratory for 14 and 15 generations out of 21 generations. At that time, the RR values of the selected colonies reached 318 and 303, respectively, compared to the non-selected colonies. Furthermore, the selected-TL and BK colonies were selected with chlorfluazuron for another 7 and 8 generations and their RR values reached 570 and 300, respectively. Thus, in this paper, chlorfluazuron selected and non-selected colonies were called TL-R and TL-S, and BK-R and BK-S strains, respectively. The TL-R and BK-R strains were occasionally selected with chlorfluazuron to maintain the resistance level high. The insects were reared at 25°C under long-day photoperiod (16 light–8 dark). The rearing technique was the same as described before.[10] Early third instar larvae were used for experiments.

Insecticides and Synergists

Insecticides used in this study were chlorfluazuron (Atabron®) 5% EC, teflubenzuron (Nomolt®) 5% EC (benzoylphenyl urea, BPU), pyriproxyfen (Sumilarv®) 10% EC (juvenile hormone analog, JHA), phenthoate (Elsan®) 50% EC (organophosphorus compound), fenvalerate (Sumicidin®) 20% EC (pyrethroid) and thiodicarb (Larvin®) technical grade 96.2% (1% solution was prepared by dissolving in a mixture of acetone: benzene:Newcol 863 at the ratio of 3:3:1, v/v) (carbamate). Synergists used were triphenyl phosphate (TPP) (95%) and piperonyl butoxicide (PB) (100%). All insecticide preparations were diluted with water containing 200 ppm spreading agent Linoh® (Nihon Noyaku Co. Ltd., Tokyo) at the desired concentrations.

Testing Technique

The leaf dipping technique was adopted.[10] For synergism and joint action studies, chlorfluazuron was mixed with the same concentration of the synergist or insecticide at the ratio of 1:1 (v/v). One exception was in case of testing the synergism with teflubenzuron (at $<LC_1$ level) in which LC_1 dose of teflubenzuron was added to the highest concentration of chlorfluazuron tested in the experiment, then this mixture was diluted to prepare lower concentrations. For control tests, cabbage leaves were dipped in the synergist solution alone for synergism studies or in distilled water containing 200 ppm of the spreading agent Linoh® for joint action experiments. Four replicates were made for each concentration as well as for the controls. Mortality was recorded one week after treatment for all mixtures and BPU or JHA applied singly. On the other hand it was recorded after three days for all the other insecticides. Larvae or pupae which did not respond to pencil tip prodding were judged as dead.

Statistical Treatment of the Data

Data were analyzed by the probit analysis[11] with a personal computer NEC PC-9801VM (Nippon Electric Co. Ltd., Tokyo).

Co-toxicity coefficient (CC) values of the binary insecticide mixtures were estimated using following formula as proposed by Sun and Johnson.[12]

$$CC=\frac{\text{Actual toxicity index of the mixture}}{\text{Theoretical toxicity index of the mixture}}\times 100$$

A CC value significantly higher than 100 indicates potentiation, a CC value close to 100 indicated a similar action and antagonistic action is indicated by CC values less than 100.

RESULTS

Synergism Studies

TPP and PB did not show any insecticidal activity under experimental conditions. The synergistic effect of TPP and PB on chlorfluazuron was tested in TL and BK strains of diamondback moth and the results are shown in Tables 1 and 2. In the TL-R strain, chlorfluazuron was synergized more with TPP and PB. The LC_{50} of the resistant strain dropped from 271 ppm to 38 and 71 ppm with TPP and PB, respectively indicating synergistic ratio (SR) value of 7.1 and 3.8. On the other hand, no clear synergism were recognized in the susceptible strain with either compounds. Also in the BK-R strain, the drop in the LC_{50} value was from 249 ppm to 36.5 and 62.8 ppm with TPP and PB, respectively indicating SR value of 6.8 and 3.9. However, PB has also exerted some synergistic activity in the susceptible strain as well.

Teflubenzuron, at the concentration of less than LC_1, was also tested for synergistic activity to chlorfluazuron. It was found that teflubenzuron (at $<LC_1$ level) has only synergized chlorfluazuron in the resistant strains and the SR values were 3.8 and 4.0 in the TL-R and BK-R strains, respectively. On the other hand, there was no synergism by teflubenzuron in the susceptible strains as shown in Tables 1 and 2.

Joint Action of Binary Mixtures of Insecticides

At the time of this study, the resistance ratio (RR) values of the TL-R and BK-R strains of diamondback

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Table 1 Synergism of chlorfluazuron by different compounds in the TL-S and TL-R strains of diamondback moth.

Mixture	TL-S strain LC$_{50}$ ppm (95% c.i.)[b]	TL-S strain LC$_{95}$ ppm (95% c.i.)[b]	SR[a] LC$_{50}$	SR[a] LC$_{95}$	TL-R strain LC$_{50}$ ppm (95% c.i.)[b]	TL-R strain LC$_{95}$ ppm (95% c.i.)[b]	SR[a] LC$_{50}$	SR[a] LC$_{95}$
Chlorfluazuron (alone)	0.475 (0.301-0.742)	17.3 (40.4-38.4)	—	—	271 (149-367)	2430 (1070-4060)	—	—
+TPP	0.366 (0.255-0.451)	6.56 (2.71-11.4)	1.3	2.6	38.7 (27.1-55.6)	524 (293-1240)	7.0	4.6
+PB	0.302 (0.194-0.473)	13.3 (6.01-42.3)	1.6	1.3	71.6 (51.3-101)	746 (317-1220)	3.8	3.2
+Teflubenzuron (<LC$_1$)	0.541 (0.363-0.795)	10.7 (3.61-19.7)	0.88	1.6	71.8 (45.4-104)	1440 (370-2790)	3.8	1.7

[a] Synergistic ratio = LC of chlorfluazuron/LC of chlorfluazuron + synergist. [b] 95% confidential interval.

Table 2 Synergism of chlorfluazuron by different compounds in the BK-S and BK-R strains of diamondback moth.

Mixtures	BK-S strain LC$_{50}$ ppm (95% c.i.)[b]	BK-S strain LC$_{95}$ ppm (95% c.i.)[b]	SR[a] LC$_{50}$	SR[a] LC$_{95}$	BK-R strain LC$_{50}$ ppm (95% c.i.)[b]	BK-R strain LC$_{95}$ ppm (95% c.i.)[b]	SR[a] LC$_{50}$	SR[a] LC$_{95}$
Chlorfluazuron (alone)	0.832 (0.544-1.30)	32.5 (9.71-67.3)	—	—	249 (173-343)	3000 (1210-5360)	—	—
+TPP	0.407 (0.282-0.601)	7.81 (3.13-13.7)	2.0	4.1	36.5 (25.6-52.0)	471 (267-1090)	6.8	6.4
+PB	0.272 (0.173-0.444)	20.2 (5.31-45.6)	3.0	1.6	62.8 (43.7-92.8)	841 (315-1430)	3.9	3.6
+Teflubenzuron (<LC$_1$)	0.748 (0.460-1.11)	26.4 (6.01-57.0)	1.1	1.2	62.1 (39.2-91.4)	1490 (375-2980)	4.0	2.0

[a] and [b] as in Table 1.

Table 3 Susceptibility levels of the TL-S and TL-R strains of diamondback moth to different insecticides and cross-resistance levels.

Insecticides	TL-S strain LC$_{50}$ ppm (95% c.i.)[b]	TL-S strain LC$_{95}$ ppm (95% c.i.)[b]	TL-R strain LC$_{50}$ ppm (95% c.i.)[b]	TL-R strain LC$_{95}$ ppm (96% c.i.)[b]	RR[a] LC$_{50}$	RR[a] LC$_{95}$
Chlorfluazuorn	0.475 (0.301-0.742)	17.3 (4.03-38.4)	271 (194-367)	2430 (1070-4060)	570	139
Teflubenzuron	0.481 (0.302-0.760)	21.9 (4.43-51.1)	15.3 (8.85-23.9)	807 (116-2150)	31.8	36.8
Pyriproxyfen	0.249 (0.144-0.521)	56.8 (3.81-170)	3.03 (2.11-4.20)	40.1 (15.3-72.1)	12.1	0.71
Phenthoate	9.68 (6.04-15.7)	652 (266-2520)	24.4 (15.7-38.8)	861 (369-3320)	2.5	1.3
Fenvalerate	36.5 (21.5-56.4)	926 (435-3500)	71.3 (41.2-113)	3840 (1600-17,000)	1.9	4.1
Thiodicarb	57.0 (36.8-87.5)	1750 (816-5680)	190 (119-332)	8510 (3070-46,700)	3.3	4.8

[a] Resistance ratio = LC of the resistant strain/LC of the susceptible strain. [b] 95% confidential interval.

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Table 4 Susceptibility levels of the BK-S and BK-R strains of diamondback moth to different insecticides and cross-resistance levels.

Insecticides	BK-S strain		BK-R strain		RR[a)]	
	LC_{50} ppm (95% c.i.)[b)]	LC_{95} ppm (95% c.i.)[b)]	LC_{50} ppm (95% c.i.)[b)]	LC_{95} ppm (96% c.i.)[b)]	LC_{50}	LC_{95}
Chlorfluazuron	0.832 (0.544-1.30)	32.5 (9.71-67.4)	249 (173-343)	3000 (1210-5360)	300	92.2
Teflubenzuron	0.440 (0.282-0.601)	12.5 (3.30-25.6)	7.24 (4.44-12.2)	575 (77.5-1520)	16.5	46.0
Pyriproxyfen	0.321 (0.191-0.570)	26.0 (3.84-65.9)	1.88 (1.33-2.81)	45.5 (17.6-84.1)	5.9	1.7
Phenthoate	21.0 (13.6-33.8)	887 (380-3160)	68.8 (45.2-107)	2430 (1110-7680)	3.3	2.7
Fenvalerate	103 (71.9-145)	1430 (834-3160)	84.3 (55.7-122)	1760 (941-4570)	0.82	1.2
Thiodicarb	185 (125-284)	3450 (1650-11,000)	221 (147-356)	5000 (2200-18,700)	1.2	1.4

a) and b) as in Table 3.

Table 5 Susceptibility levels of the TL-S and TL-R strains of diamondback moth to insecticides mixtures and co-toxicity coefficient value.

Insecticide mixtures	TL-S strain			TL-R strain		
	LC_{50} ppm (95% c.i.)[b)]	LC_{95} ppm (95% c.i.)[b)]	CC[a)] (LC_{50})	LC_{50} ppm (95% c.i.)[b)]	LC_{95} ppm (95% c.i.)[b)]	CC[a)] (LC_{50})
Chlorfluazuron						
+Teflubenzuron	0.0691 (0.0513-0.0911)	0.468 (0.290-1.02)	692	2.24 (1.23-3.60)	88.7 (35.6-490)	1290
+Pyriproxyfen	0.0428 (0.0201-0.0702)	4.31 (1.57-25.7)	1450	3.02 (2.11-4.20)	40.1 (15.3-72.1)	1940
+Phenthoate	0.895 (0.612-1.34)	15.9 (8.12-44.4)	101	141 (97.3-216)	1950 (938-6690)	31
+Fenvalerate	3.29 (2.34-4.85)	48.0 (25.9-121)	28	108 (79.1-151)	837 (497-1910)	104
+Thiodicarb	2.29 (1.63-3.31)	39.6 (21.0-102)	41	119 (75.3-175)	2790 (724-5530)	187

a) Co-toxicity coefficient. b) 95% confidential interval.

moth to chlorfluazuron have reached 570 and 300, respectively, compared with the susceptible (non-selected) strains. This difference in the RR values between two strains was partially due to the difference in the susceptibility levels of the TL-S and BK-S strains since LC_{50} values of the TL-R and BK-R strains were very close, 271 and 249 ppm, respectively (Tables 3 and 4).

The TL-R and BK-R strains have shown some cross-resistance to teflubenzuron with RR values of 31.7 and 16.5, respectively (at the LC_{50} level). Also at the LC_{95} level, the RR values were high (37 and 46 for the TL and BK strains, respectively). A very low level of cross-resistance (at the LC_{50} level) to pyriproxyfen (JHA) was recognized especially in the TL strain. However, the RR value at the LC_{95} level for both strains showed no evidence for cross-resistance to this compound. Also there was no cross-resistance to any of the other insecticides tested as clear from the RR values listed in Tables 3 and 4.

The TL and BK strains of diamondback moth were tested against binary mixtures of insecticides in order to assess the joint action of these binary mixtures by estimating the CC values of each mixture. The results of this test are listed in Tables 5 and 6.

Joint action, expressed by the CC values, was only high with mixtures of chlorfluazuron + teflubenzuron and chlorfluazuron + pyriproxyfen in both TL and BK strains. Joint action was higher in the resistant strains than in the susceptible ones. In the TL strain, CC value with chlorfluazuron + teflubenzuron mixture were 692 and 1290 in the susceptible and resistant strains, respectively. Also for chlorfluazuron + pyriproxyfen, the CC values were 1450 and 1940 in the susceptible and resistant strains, respectively. The situation with the BK strains

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Table 6 Susceptibility levels of the BK-S and BK-R strains of diamondback moth to insecticides mixtures and co-toxicity coefficient value.

Insecticide mixtures	BK-S strain			BK-R strain		
	LC_{50} ppm (95% c.i.)[b]	LC_{95} ppm (95% c.i.)[b]	CC[a] (LC_{50})	LC_{50} ppm (95% c.i.)[b]	LC_{95} ppm (95% c.i.)[b]	CC[a] (LC_{50})
Chlorfluazuron						
+Teflubenzuron	0.177	4.01	492	1.30	7.31	1080
	(0.0711-0.200)	(1.12-8.30)		(0.94-1.72)	(4.73-14.9)	
+Pyriproxyfen	0.0502	10.1	926	0.207	9.33	1830
	(0.0212-0.0923)	(2.91-106)		(0.0935-0.361)	(4.44-34.1)	
+Phenthoate	0.750	16.9	213	83.2	1010	129
	(0.511-1.11)	(9.03-41.5)		(58.4-117)	(397-1700)	
+Fenvalerate	3.04	125	54	73.5	1440	171
	(1.94-4.61)	(34.5-261)		(49.9-112)	(698-4400)	
+Thiodicarb	5.16	135	32	102	1130	229
	(3.00-7.71)	(37.6-268)		(72.3-148)	(611-307)	

[a] and [b] as in Table 5.

was not different from that in the TL strain. The CC values were 492 and 1080 for the chlorfluazuron + teflubenzuron mixture and 926 and 1830 for the chlorfluazuron + pyriproxyfen mixture in the susceptible and resistant strains, respectively. On the other hand, the CC values for the other mixtures in both strains have shown similar or independent action with no sign of potentiation evidenced by the CC values being close to or less than 100 as shown in Tables 5 and 6.

DISCUSSION

Generally, synergism studies have been reported mainly as inhibition of metabolic detoxification of insecticides.[13] These studies are usually useful for the prediction of resistance mechanisms to conventional insecticides[6,7,13,14] as well as to BPUs.[9,15,16] The rèmarkablė enhancement of the toxicity of chlorfluazuron by TPP in the chlorfluazuron-resistant strains compared with susceptible strains suggests the possibility that a TPP-sensitive enzyme system (s) might be involved in the chlorfluazuron resistance mechanism in this insect pests. TPP is a typical carboxylesterase inhibitor, thus the exact nature and specifications of this enzyme system (s) have yet to be clarified. Qualitative and/or quantitative difference in metabolic enzyme systems between the susceptible and the resistant insects may explain the higher synergistic ratios obtained in the resistant strains than in the susceptible ones.

PB showed high SR values in TL-R, BK-R and BK-S, but not in TL-S strains. Fauziah and Wright[16] have reported that PB increased the toxicity of chlorfluazuron and teflubenzuron in chlorfluazuron-R and teflubenzuron-R strains of diamondback moth from Malaysia and there was no synergism in the susceptible strains. It was reported that PB synergized PH 60-51,[17] chlorfluazuron and teflubenzuron[18] in IGR-resistant Taiwan strains of diamondback moth larvae, suggesting that cytochrome P_{450} monooxygenase is the primary factor for resistance in these compounds. However addition of MGK 264, another cytochrome P_{450} monooxygenase inhibitor, was less effective in synergizing teflubenzuron in diamondback moth.[17] Thus, the exact situation does not seem to be clear since synergism in the susceptible strains of the same populations was not tested in the last two reports by Pern *et al.*[17] and Cheng *et al.*[18] Therefore the involvement of these enzyme systems in the resistance mechanisms is not conclusive unless it is confirmed that the same synergist does not enhance the insecticidal activity in the susceptible individuals. Synergism of BPUs in different insect species by different compounds is well documented. For example, Primpricar and Georghiou[19] stated that diflubenzuron was synergized by PB and sesamex, cytochrome P_{450} monooxygenase inhibitors, in *Musca domestica* and the SR values were significantly higher in the diflubenzuron-resistant strain than in the susceptible strain, indicating a significant role for cytochrome P_{450} enzymes in resistance to this compound.

Addition of teflubenzuron at the concentration of less than LC_1 level (to eliminate any lethal effect caused by teflubenzuron), remarkably increased chlorfluazuron toxicity. The possible explanation for that might be the interference with chlorfluazuron degradation enzyme, since the SR of teflubenzuron (at $<LC_1$ level) was higher in the resistant strains than in the susceptible strains. This indicates that the above mentioned interference was responsible for chlorfluazuron resistance.

The susceptibility levels of the TL and BK strains of diamondback moth to different group of insecticides revealed that the chlorfluazuron-resistant strains did not show any cross-resistance to any of the conventional insecticides tested. This confirms that the results obtained with the same strains when they were tested at lower chlorfluazuron resistance levels,[10] which indicates

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the lack of cross-resistance to conventional insecticides in the chlorfluazuron-resistant diamondback moth strains. On the other hand, the development of higher levels of chlorfluazuron resistance in diamondback moth compared to those reported earlier has led to the development of higher levels of cross-resistance to teflubenzuron than those reported in the earlier study.[10] In a report by Fauziah and Wright,[16] it was reported that selection of a field susceptible strain of diamondback with chlorfluazuron, which resulted in RR=181, led to cross-resistance to teflubenzuron (RR=306) and vice versa, selection with teflubenzuron, which resulted in RR=113, led to cross-resistance to chlorfluazuron (RR=36). This might suggest that the mechanisms of resistance to these two insecticides are more or less related to each other. Concerning pyriproxyfen, in spite of the RR values, at the LC_{50} level, in the TL and BK strains (12- and 5-fold, respectively), it is unlikely that there is a clear cross-resistance to this compound if we consider the RR values at the LC_{95} which were 0.7 and 1.7 in the TL and BK strains, respectively.

The present study has revealed strong potentiation with mixtures of chlorfluazuron + teflubenzuron and chlorfluazuron + pyriproxyfen. Higher CC values were obtained in the resistant strains than in the susceptible ones. On the other hand, varying degree of similar or independent action were detected when chlorfluazuron was mixed with the other three groups of insecticides represented by phenthoate, fenvalerate and thiodicarb. It was reported by El-Guindy *et al.*[20] that in the diflubenzuron-susceptible and resistant strains of *Spodoptera littorals* Boisd., high levels of potentiation were developed when diflubenzuron was combined with methoprene and progressively less with fenvalerate, methomyl and cypermethrin. The clear potentiation action with chlorfluazuron + teflubenzuron mixture may be attributed to the fact that both chitin syntheses inhibitors are probably affecting or interfering with target site of each other, which may lead to the potentiation obtained with this mixture. The CC value were remarkably higher in the resistant strains than in the susceptible strains, which might elucidate a probable inhibition of the insecticide metabolic enzymes of each other supported by the synergistic effect of teflubenzuron, at the nontoxic concentration of less than LC_1, on chlorfluazuron, only in the resistant strains. Horowitz *et al.*[21] have also reported that the potentiation mechanism of binary mixtures of insecticides could be related to the disruption of different physiological systems of each component of the mixture.

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要　　約

クロルフルアズロン感受性および抵抗性コナガにおけるクロルフルアズロンと共力剤および殺虫剤との共力作用ならびに連合作用

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クロルフルアズロン感受性および抵抗性タイ国産コナガ(TLおよびBP系統)における，TPPおよびPBとクロルフルアズロンの共力作用を調べた．両抵抗性系統におけるTPPとPBの共力作用係数は，いずれの抵抗性系統ともそれぞれ7と4であった．感受性TL系統ではTPPおよびPBとも共力作用は認められなかったが，感受性BK系統ではTPPは2，PBは3であった．これらの結果から，TPPに感受性の酵素系がクロルフルアズロン抵抗性に関与していることが考えられた．致死量以下($<LC_1$)のテフルベンズロンをクロルフルアズロンと同時に処理すると，クロルフルアズロン抵抗性系統においては高い共力作用が認められたが，感受性系統では共力作用は認められなかった．このことは，テフルベンズロンがクロルフルアズロン分解酵素を阻害していることを示唆している．クロルフルアズロンとテフルベンズロンやピリプロキシフェンとの混合処理は，特に抵抗性系統で高い連合作用が認められた．一方，フェンバレレート，フェントエートやチオディカルブとは連合作用は認められなかった．テフルベンズロンやピリプロキシフェンとの高い連合作用は，これら殺虫剤によるクロルフルアズロン分解酵素あるいは作用点の阻害によるものと考えられた．

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