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Study on Cross-resistance between BPU-type IGRs and Other Insecticides Including *Bacillus thuringiensis* and Abamectin in the Diamondback Moth, *Plutella xylostella* L.[1]

Ching-Hua Kao and Edward Y. Cheng[2]

Abstract: Investigation of cross-resistance of diamondback moth(DBM), *Plutella xylostella* L., which resisted to benzoylphenyl urea(BPU)-type insect growth regulator (IGR), among four organophosphorus insecticides, two carbamates, two synthetic pyrethroids, four IGRs, Thuricide and Abamectin was conducted in this study. The IGR-selected strains did not show strong cross-resistance to test insecticides except carbofuran. A relatively high resistance to synthetic pyrethroids was recorded as synthetic pyrethroid resistance of the DBM is an existing phenomenon in Taiwan. All IGR-resistant strains were still highly sensitive to Thuricide and Abamectin. Cross-resistance among different IGRs is significant in different amplitudes. Hexaflumuron was the least affected by IGR cross-resistance and followed by chlorfluazuron, while flufenoxuron and teflubenzuron confronted with the most serious cross-resistance problem. The IGR-resistance in DBM is chemical structure-related. Analyses of structure-activity relationship in both susceptible and resistant strains indicated both 3,5-dichloro- and a large side moiety at position-4 on the phenyl ring of BPU are beneficial to reduce the IGR-resistance in DBM.

Key words: *Plutella xylostella*, Cross-resistance, Benzoylphenyl urea , Insect growth regulator, Insecticides.

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INTRODUCTION

In recent years, developing safer insecticide is a major goal for pesticide industry, and critical physiological development stage of arthropods becomes the target for new insecticide design. The development of benzoylphenyl urea (BPU)-type insect growth regulator (IGR) served as a successful example since its action is targeted on molting, which is a specific phenomenon in arthropods. Diflubenzuron is the first product of this new category of insecticide particular effective in dipterous pests. Many researchers reported that different chemical analogues of IGRs affect differently in various insect species. Consequently, compounds with specific action on lepidopterous such as teflubenzuron were developed later.

For the control of diamondback moth (*Plutella xylostella*, DBM), teflubenzuron is the first successful IGR, and followed by chlorfluazuron. Both compounds have gained early success in DBM control. Unfortunately, the rapidly developed IGR-resistance of the DBM had rendered the effectiveness of teflubenzuron to minimum when the control effect of chlorfluazuron was also decreased significantly. Evidences suggested that the major mechanism for IGR-resistance is stemmed from a newly induced mixed function oxidase (MFO) [3], which has no relation to the MFOs responsible for the existing resistance of synthetic pyrethorids and carbamates.

Before 1988, studies on both laboratory and field strains of DBM showed no evidence that traditional insecticides would cause cross-resistance to IGRs [5,11]. The early success of IGR on DBM control in Taiwan also practically confirmed no cross-resistance from other insecticides. IGR-resistance in DBM is originated from a new and induced MFO complex [3], but whether there is cross effect of IGR-resistance on other insecticides is unclear. Besides, whether the IGR-resistance is a universal response or just specific to individual IGR in DBM is also unknown. The above information is needed in DBM resistance management. The purpose of this study is tried to clarify both questions.

MATERIALS AND METHODS

Insecticides used:

Four IGRs used in this study were chlorfluazuron (CFA), 5% EC (Ishihara Sangyo Kaisha Limited); teflubenzuron (TFB), 15% SC (Celamerck GmbH & Co. KG); hexaflumuron (HXF), 10% EC (DowElanco) and flufenoxuron (FFO), 10% EC (Shell International Chemical Company Limited).

Commercial insecticides used for comparison were methomyl 90% WP, carbofuran 40.64% FP, mevinphos 25.3% EC, methamidophos 50% EC, phenthoate 50% EC, profenofos 43% EC, cypermethrin 5% EC, fenvalerate 20% EC, Abamectin® 2% S and Thuricide® 3% WP.

Field IGR selection of resistant DBM:

Four separate fields were chosen for individual IGR-resistant DBM selection. The resistance was expected after intensively spraying IGRs for 12 months, a period for previously recorded IGR-resistance development in DBM of Taiwan [3]. The spraying schedule was set on a 10-day interval and the doses used in selection were based on or equivalent to that of the already registered CFA and TFB as follows:

(1) CFA 5% EC in 2,000X dilution
(2) TFB 15% SC in 4,000X dilution
(3) HXF 10% EC in 4,000X dilution
(4) FFO 10% EC in 4,000X dilution

Each field site was divided into two parts, and cruciferous vegetables were planted in the half-field alternatively to maintain a continuous DBM population. The selection site was at least 1 kilometer separated from other vegetable fields by rice paddy. Inundate release of the susceptible DBM in selection site had been done in the early stage of selection to reduce the impact of possible invasion of field IGR-resistant DBM.

Insects used:

Three field-collected resistant DBM strains[2] and 4 field IGR-selected DBM strains were tested against a

native susceptible DBM strain, and they were:

I. Susceptible strain : Taiwan native I-lan (IL) DBM strain.

II. Resistant strains:

i. Field-collected IGR-resistant DBM strains

A. RS1 - with previous TFB usage record

B. RS2 - with previous TFB and CFA resistance record

C. RS3 - with previous CFA usage record

ii. Field IGR-selected DBM strains

A. R-CS - selected by CFA only

B. R-TS - selected by TFB only

C. R-HS - selected by HXF only

D. R-FS - selected by FFO only

Bioassay methods:

I. Spray tower method: The susceptibilities of DBM to methomyl, carbofuran, mevinphos, methamidophos, phenthoate, profenofos, cypermethrin and fenvalerate were tested as described in Cheng *et al.*[1]. One milliliter of insecticide solution was transferred into the holding tube of Burkard Potter Spray Tower and sprayed on leaf disc. After air-dried, the leaf disc was inverted and loaded with fifteen third instar DBM larvae, and sprayed with another milliliter of the same insecticide solution. Treated larvae and leaf discs were transferred into the petri dish, and total of 60 larvae in 4 subsets was treated for each dosage. The post-treatment holding condition was controlled at 25℃ in a constant temperature growth chamber. The leaf discs used were 24 cm^2 and changed to fresh untreated leaf discs at the end of 48 hours, hence the IGR-treating period was fixed at 48 hours.

II. Leaf dipping method: The susceptibilities of different DBM strains to Abamectin, Thuricide, CFA, TFB, FFO and HXF were determined as described by Cheng and Kao[2,9], and the IGR dipping solutions were diluted at concentration increment of 10-fold for the susceptible strain as follows:

CFA - 1.67, 0.167, 0.0167 and 0.00167ppm

TFB - 5.00, 0.500, 0.0500 and 0.00500ppm

FFO - 3.33, 0.333, 0.0333 and 0.00333ppm

HXF - 3.33, 0.333, 0.0333 and 0.00333ppm

In testing resistant DBM strains, the dilutions were also set at 10-fold increment for IGRs except HXF.

CFA - 500, 50, 5 and 0.5ppm

TFB - 1,500, 150, 15 and 1.5ppm

FFO - 1,000, 100, 10 and 1.0ppm

HXF - 64, 16, 4 and 1.0ppm

Cabbage leaves were washed and air-dried first, and leaves were punched into discs of 3.5 cm in diameter. Total of 20 leaf discs were prepared for each dosage and leaf discs were dipped for 5 seconds in IGR solutions containing 333ppm Triton X-100 and left to air-dry. For the control test, cabbage leaf discs were dipped in a 333ppm Triton X-100 solution only and air-dried on wire rack. In each petri dish, three leaf discs were used in the beginning and 15-20 third instar DBM larvae were put onto the treated leaves. At 48 hours after treatment, these leaf discs were discarded and changed to the other two treated leaf discs that been stored at 5℃ until pupation. Total of sixty DBM larvae in 4 subsets for each dosage were subjected to treatment.

Assessments:

Mortality assessments of DBM to methomyl, carbofuran, mevinphos, methamidophos, phenthoate, profenofos, cypermethrin and fenvalerate were made 48 hours after the spray tower treatment. For Abamectin and Thuricide, the mortalities were recorded at 24, 48, 72, 96 and 120 hours, the same as those for IGR, after the start of treatment. Analysis was made by correcting with the control first, then analyzed by Probit analysis[8]. If the mortality in control was over 8%, the test was abandoned and repeated.

RESULTS

In an early study, we had reported TFB and CFA were very effective in controlling the multiple resistant DBM, which is resistant to organophosphorus compounds, carbamates and synthetic pyrethroids[5]. By 1988, IGR were still effective against DBM and suffered no cross-resistance from any known insecticides. In Taiwan, the field DBM has developed resistance to IGR during March 1988 to early 1989, and the resistance ratios were 200 and 115 fold for TFB and CFA between the resistant and the susceptible strains, respectively[3].

Table 1. Susceptibilities of the susceptible and individually BPU-selected DBM strains to 10 insecticides

Insecticides	LC_{50} (ppm) and slope				
	S-IL	R-CS[z]	R-TS	R-HS	R-FS
Organophosphorus compounds					
Mevinphos					
LC_{50}	165.8	356.9	515.3	611.5	732.2
Slope	3.08	2.70	3.11	3.42	4.46
Methamidophos					
LC_{50}	350.7	947.8	1387.5	1665.8	2959.4
Slope	3.02	2.88	5.10	3.35	3.85
Phenthoate					
LC_{50}	283.9	1360.5	1606.6	3236.2	750.5
Slope	1.46	1.19	0.74	0.71	0.65
Profenofos					
LC_{50}	172.4	963.1	3245.8	1213.1	2107.5
Slope	0.95	1.19	2.19	2.22	2.57
Carbamates					
Methomyl					
LC_{50}	793.1	6281.1	4265.4	7294.5	11110.9
Slope	1.85	1.59	2.40	3.86	2.13
Carbofuran					
LC_{50}	91.0	7114.6	16889.5	15625.6	7213.9
Slope	1.08	0.95	0.74	1.12	1.63
Synthetic pyrethroids					
Cypermethrin					
LC_{50}	41.0	569.3	819.3	499.4	415.9
Slope	0.68	1.62	1.88	2.79	3.30
Fenvalerate					
LC_{50}	41.0	3607.3	1608.4	1731.7	872.9
Slope	0.66	1.05	1.31	2.32	2.02
Bioinsecticides					
Abamectin					
LC_{50}	0.002	0.009	0.028	0.005	0.007
Slope	1.53	1.05	1.71	1.43	1.11
Thuricide					
LC_{50}, in d.f.[y]	$4x10^{-5}$	$6.3x10^{-5}$	$9x10^{-5}$	$10.3x10^{-5}$	$4.4x10^{-5}$
Slope	2.05	0.80	1.81	1.42	0.70

[z] R-CS: chlorfluazuron-selected resistant strain; R-TS: teflubenzuron-selected resistant strain; R-HS: hexaflumuron-selected resistant strain; R-FS: flufenoxuron-selected resistant strain.
[y] d.f.= dilution factor.

The cross-resistance of IGR to other insecticides and IGRs can only be understood by testing the IGR-selected DBM. The wild IGR-resistant DBM were also tested for cross-resistance effect among different IGRs to verify the results of IGR-selected DBM. After selecting for one year, the susceptibilities of 4 individual IGR-selected DBM

strains to 10 commonly used insecticides from 4 categories were summarized in Table 1. The resistance ratios were calculated with respect to the susceptible IL-strain in Table 2.

Table 2. Resistance ratios of 4 individually BPU-selected DBM strains to 10 insecticides

	Resistance ratio (R.R.)			
	R-CS[z]	R-TS	R-HS	R-FS
Organophosphorus compounds				
Mevinphos	2.2	3.1	3.7	4.4
Methamidophos	2.7	4.0	4.7	8.4
Phenthoate	4.8	5.7	11.4	2.6
Profenofos	5.6	18.8	7.0	12.2
Carbamates				
Methomyl	7.9	5.4	9.2	14.0
Carbofuran	78.2	185.6	171.7	79.3
Synthetic pyrethroids				
Cypermethrin	13.9	20.0	12.2	10.1
Fenvalerate	88.0	39.2	42.2	21.3
Bioinsecticides				
Abamectin	4.5	14.0	2.5	3.5
Thuricide	1.6	2.3	2.6	1.1

[z] Footnotes the same as in Table 1.

For the organophosphorus compounds, the resistance level (2.2-18.8) is similar to those field strains observed previously[1,4]. Hence the cross-resistance from IGR to organophosphorus compound is rather unlikely. For the carbamates, methomyl resistance in DBM is usually higher than carbofuran resistance[4]. However, all IGR-selected strains showed higher carbofuran resistance than methomyl (Table 2). Fahmy *et al.*[6] had reported that no cross-resistance from IGR to other insecticides and we have also confirmed that carbofuran resistance in LC-strain is not cross to IGRs, but the IGR-resistance seemed to have a strong cross-resistance to carbofuran. Both IGR and carbofuran confront with MFO-generated resistance[5]. It seems that IGR-induced MFO has wider substrate spectrum than the MFO induced by carbofuran. However, carbofuran has been excluded from rotation for DBM resistance management in Taiwan because it induces resistance easily as well as its toxicity to human and non-target organisms is high.

In IGR-selected strains, the resistance to synthetic pyrethroids is strong and the resistance ratios for fenvalerate and cypermethrin are 21.3-88.0 and 10.1-20.0 fold, respectively (Table 2). The resistance is similar to those previously observed synthetic pyrethorids resistance in field DBM[4] indicating that IGR-resistance has no special impact on the synthetic pyrethorids resistance although both resistances are MFO-originated. The results in Table 2 showed no cross-resistance from IGRs to Thuricide or Abamectin, which agreed with the conclusion of Fauziah and Wright[7].

In regard of the IGR-resistance, although HXF and FFO had never been used in Taiwan, both had confronted with resistance problem in the field strains (RS1 - RS3 in Tables 3 and 4). The cross-resistance test of 4 IGRs in four

BPU-selected DBM strains were presented in Table 5. The IGR-resistance in each selected strain is not specific to its inducing compound, and a rather general trend of compound-related resistance is observed. In all IGR-selected strains, TFB suffered the worst resistance (Tables 5 and 6) and the followed by FFO, CFA and HXF. Similar result was observed in 3 wild resistant strains (Tables 3 and 4).

Table 3. The LC_{50}s (in ppm) and slopes of the susceptible DBM and 3 wild resistant strains to 4 BPUs

	S-IL	RS1	RS2	RS3
CFA				
LC_{50}	0.12	5.62	4.01	46.20
Slope	0.84	0.85	0.65	0.72
TFB				
LC_{50}	0.13	41.70	9.93	85.00
Slope	0.86	0.54	0.65	0.47
HXF				
LC_{50}	0.24	3.98	5.74	10.90
Slope	0.99	1.43	1.40	1.38
FFO				
LC_{50}	0.23	15.10	11.40	192.30
Slope	0.97	0.58	0.61	0.48

Table 4. Resistance ratios of 3 wild resistant DBM strains to different BPUs

	RS1	RS2	RS3	Average
Resistance ratio (R.R.)				
HXF	16.4	23.7	45.1	28.4
CFA	47.1	33.6	387.1	155.9
FFO	64.5	48.9	822.1	311.8
TFB	322.3	76.7	656.5	318.5
Resistance relative to HXF				
HXF[z]	1.00	1.00	1.00	1.00
CFA	2.87	1.42	8.58	4.29
FFO	3.93	2.06	18.23	8.07
TFB	19.69	3.24	14.56	12.48

[z] R.R. of HXF is 28.4.

A general conclusion has been reached for both wild resistant and IGR-selected strains that HXF is the least affected by IGR-resistance. When we set the susceptibility of HXF in each strain as the index of 1, the relative resistance were obtained in the second part of Table 4 (1:4.29:8.07:12.48) and Table 6 (1:3.28:7.27:21.97). By comparing any two IGRs in both wild and IGR-selected strains, the relative effective dosages are calculated in Table 7. All these results indicated the existing cross-resistance amongst different IGRs and the degree of resistance is a compound-dependent phenomenon among IGRs. The IGR cross-resistance was demonstrated between CFA and TFB in DBM by Fauziah and Wright[7] and Fahmy *et al.*[6]. In this study, the resistance to FFO (Table 5) was high and almost equivalent to that of TFB, which was different from the result of Fauziah and Wright[7]. On the other hand, HXF suffered the least IGR-resistance, which was partially agreed with the test reports of Fauziah and Wright[7] and Kobayashi *et al.*[10].

Table 5. The LC_{50}[S] and slopes of the susceptible DBM and 4 individually BPU-selected field strains to BPUs

Insecticides	LC_{50} (ppm) and slope				
	S-IL	R-CS[Z]	R-TS	R-HS	R-FS
CFA					
LC_{50}	0.12	67.20	26.00	1.50	3.90
Slope	0.84	0.53	0.70	0.55	0.62
TFB					
LC_{50}	0.13	126.00	123.10	92.10	115.00
Slope	0.86	0.45	0.44	0.57	0.52
HXF					
LC_{50}	0.24	16.20	17.90	5.90	6.90
Slope	0.99	1.07	0.75	1.85	0.81
FFO					
LC_{50}	0.23	144.10	88.20	1823.20	50.30
Slope	0.97	0.50	0.36	0.38	0.41

[Z] Footnotes the same as in Table 1.

Table 6. Resistance ratios of 4 individually BPU-selected DBM strains to different BPUs

	R-CS[Z]	R-TS	R-TS	R-FS	Average
Resistance ratio					
HXF	66.9	74.0	24.5	28.5	48.5
CFA	564.7	218.5	12.6	32.8	207.2
FFO	615.8	376.9	-	215.0	402.6
TFB	976.7	954.3	714.0	891.5	884.1
Resistance relative to HXF					
HXF[Y]	1.0	1.0	1.0	1.0	1.0
CFA	8.4	3.0	0.5	1.2	3.3
FFO	9.2	5.1	-	7.5	7.3
TFB	14.6	12.9	29.1	31.3	22.0

[Z] Footnotes the same as in Table 1.
[Y] R.R. of HXF is 48.5

Table 7. Effective dosage equivalence of BPUs in resistant DBM strains

2^{nd} BPU/1^{st} BPU	Relative effective dosage[Z]	
	Wild strains	Individually BPU-selected strains
CFA/HXF	3.20	4.29
FFO/HXF	7.20	8.07
TFB/HXF	22.00	12.48
FFO/CFA	2.25	1.88
TFB/CFA	6.88	2.91
TFB/FFO	3.06	1.55

[Z] No significant difference between wild and BPU-selected strains was found, but cross-resistance among BPUs is significant.

DISCUSSION AND CONCLUSION

It has been concluded in earlier study[4] that the resistance from other insecticides have no cross effect on BPU-type IGRs in DBM, and the IGR-induced resistance has no cross effect to organophosphorus compounds, synthetic pyrethroids, 2 bio-insecticides and carbamates except carbofuran. Other than the strong cross-resistance to carbofuran, the lack of cross-resistance amongst IGRs, carbamates and synthetic pyrethroids confirmed those induced MFOs in DBM are very diverse in their specificity[4].

A common IGR-resistance among IGRs is confirmed in this study. The only difference among IGRs is the compound-dependent amplitude in resistance, which is strongly related to the molecular structure of IGRs. The phenomenon is rather clear since earlier developed IGRs such as diflubenzuron and triflumuron are not active in lepidopterous pests like DBM. By modifying the chemical structure, TFB and three other tested IGRs showed effective activity. The structure specificity of IGR molecular not only affects the ability of activity but also extends to their degradation in DBM. Metabolic study will clarify how the chemical structures of IGRs affect their biological activity as well as their MFO degradation.

Combining the information of previous study in the susceptible DBM[2,5], equivalent dosages were estimated at 3,715 : 435 : 1 : 1 : 2 : 2 for diflubenzuron : triflumuron : TFB : CFA : FFO : HXF. After adding the synergist PB to inhibit the activity of natural, not induced, MFO for diflubenzuron and triflumuron, the equivalent dosages changed to 234 : 180 : 1 : 1 for diflubenzuron : triflumuron : TFB : CFA[5]. The needed dosages of diflubenzuron and triflumuron were still too high, hence they were recognized as non-effective IGRs for DBM, while CFA and TFB were considered as effective. HXF and FFO were not tested in the study of Cheng *et al.*[5], but their effective dosages were in the same range of CFA and TFB[2]. In other words, when there is no interference from resistance, 4 effective IGRs can be considered ideal in their molecular design and fit to function as insect growth regulators for DBM.

In field-collected IGR-resistant strains (RS1, RS2 and RS3) that had been exposed to CFA and TFB, the effective dosages of 4 IGRs had changed drastically and HXF suffered the least resistance. By fixing the resistance of HXF as index of 1.0, the relative resistance strength of other IGR can be calculated (Table 6). The relative insecticidal efficacy between any two IGRs were then compared in Table 7.

To examine the structure-activity relationship, the equivalent dosages and the chemical structures of 6 IGRs were listed and compared in Fig. 1. In the susceptible strain, it is clear that the side moieties in positions -2, -3, -5 and -6 of phenyl ring caused significant difference between 4 effective and 2 non-effective IGRs. Less complicated diflubenzuron and triflumuron with unoccupied positions -2, -3and -5 (Fig. 2) of phenyl ring were more susceptible to the metabolism of natural MFO, and were also not very effective even with the help of PB. In 4 effective IGRs, the bio-activity of individual side moiety on phenyl ring is rather indistinguishable in the susceptible DBM.

In the resistant strains, various combinations of side moieties on phenyl ring caused significant resistance difference. If we compared the phenyl ring with all the side moieties of 4 effective IGRs illustrated in Fig. 2, position-2 is either unoccupied or occupied by a fluoro- moiety, while positions-3 and -5 are either unoccupied or occupied by a 3,5-dichloro- substitute. Nevertheless, position-4 varied from a fluoro- moiety, a ring structure with side moieties, to a tetrafluoroethoxy chain.

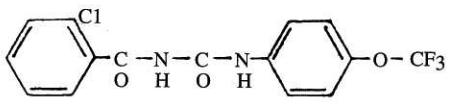
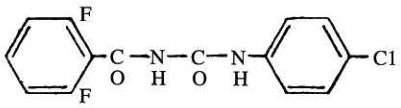
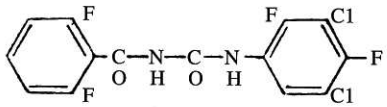
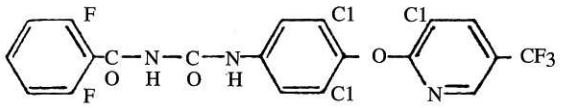
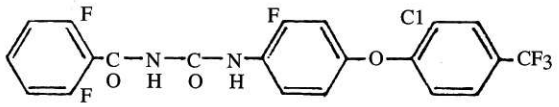
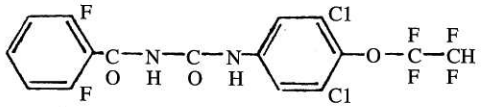
Chemical structures	Compound names	Equivalent dosage	
		Without PB	With PB
	Triflumuron	435	(180)
	Diflubenzuron	3,715	(234)
	Teflubenzuron	1	-
	Chlorfluazuron	1	-
	Flufenoxuron	2	-
	Hexaflumuron	2	-

Fig. 1. Comparison of chemical structures and equivalent dosages (LC_{50} in ppm) for 6 BPUs against the susceptible diamondback moth.

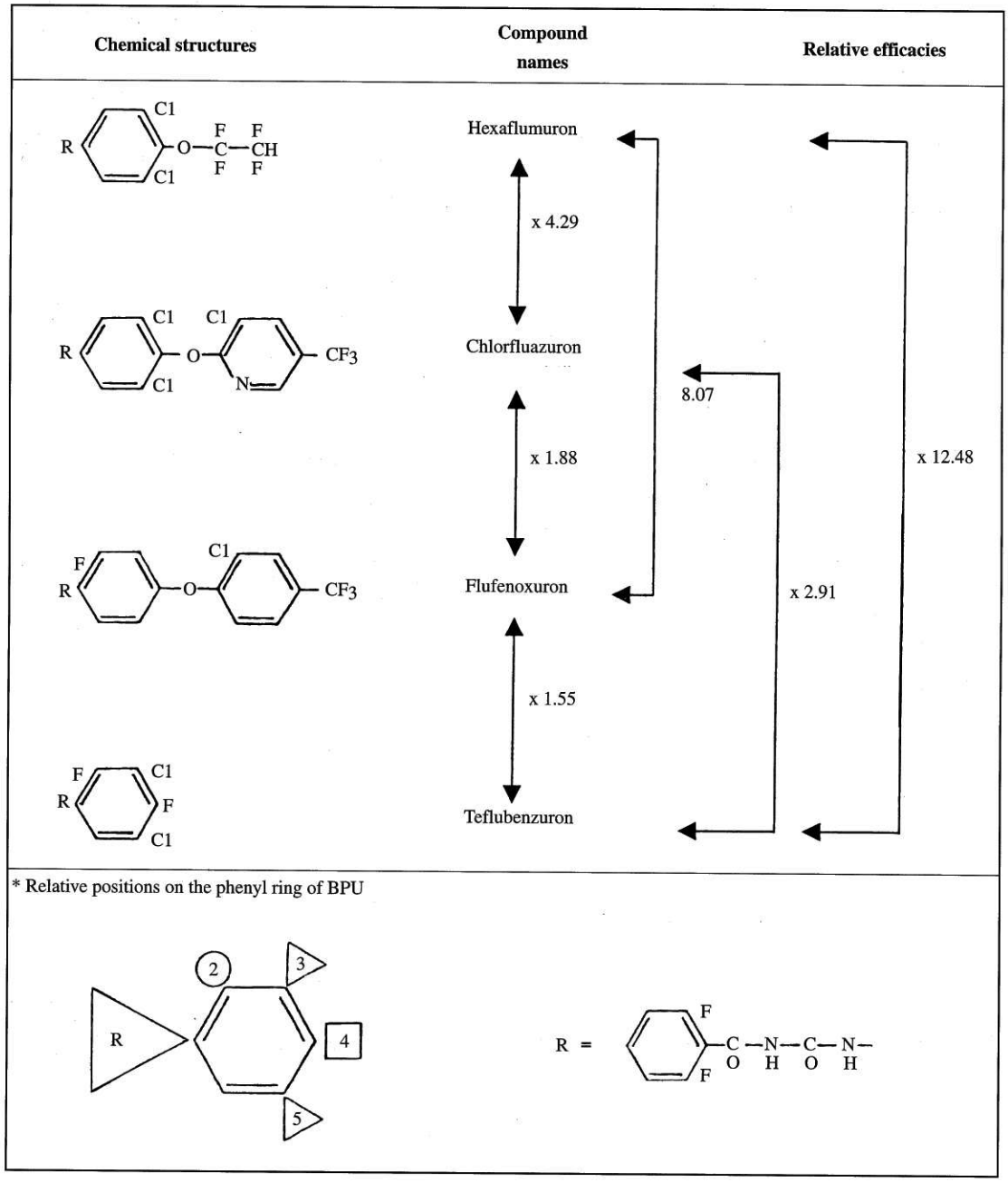


Fig. 2. Relative efficacy between any two BPUs in resistant DBM strains.

A large side moiety at position-4 combined with the 3,5-dichloro-moiety can probably reduce the resistance to a lesser extend as both HXF and CFA demonstrated (Table 7). For individual comparison, the tetrafluoroethoxy chain of HXF performed better than the heterocyclic ring of CFA against the IGR-resistance in DBM. Without the 3,5-dichloro-structure, FFO met high IGR-resistance despite its structural similarity to CFA. With the 3,5-dichloro- structure but lacking a large side moiety at position-4, TFB also confronted with high resistance. The resistance difference between HXF and TFB reached 12.5 fold and the tetrafluoroethoxy chain at position-4 might be the major cause. The 2-fluoro-moiety did not cause much difference in resistance as both HXF and CFA lacked it.

By keeping the 3,5-dichloro-moiety on phenyl ring and making further modification on the side chain of position-4, chemists of pesticide industry may be able to synthesize better BPUs to counter the IGR-resistance problem in DBM.

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小菜蛾對BPU類生長調節劑及其他殺蟲劑交互抗性之研究[1]

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摘要：本研究測試抗benzoylphenylurea(BPU)類生長調節劑之小菜蛾對有機磷劑、氨基甲酸鹽劑、合成除蟲菊精、BPU 類生長調節劑、蘇力菌及阿巴汀是否具有交互抗性。結果顯示，以 BPU 類生長調節劑篩選之品系對加保扶有交互抗性。抗BPU類生長調節劑之小菜蛾品系對其他受測藥劑均不具交互抗性，且對蘇力菌及阿巴汀之感度仍極高。BPU類中不同的生長調節劑間則具交互抗性，惟程度不一，其中，hexaflumuron 受交互抗性之影響最小，其次爲 chlorfluazuron，而 flufenoxuron 與 teflubenzuron 則有極嚴重之交互抗性。此一現象在田間抗 BPU 類生長調節劑之品系，及以單劑汰選出之抗性品系均相同。而於田間篩選抗性時，則以已在本省登記之chlorfluazuron及 teflubenzuron 較 flufenoxuron 及 hexaflumuron 快速，可能與前兩項藥劑已在台灣使用有關。再由BPU類生長調節劑之化學結構，以及感、抗性品系之測試結果分析推測，BPU類生長調節劑 phenyl-環上之 3,5-dichloro-結構與位置4上之大型鍵結側基(moiety)，可降低小菜蛾對 BPU 類生長調節劑之抗性程度。

關鍵詞：小菜蛾、BPU類生長調節劑、殺蟲劑、抗藥性、交互抗性。

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