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Insecticide Susceptibility of the Oriental Fruit Fly (Bactrocera dorsalis (Hendel))(Diptera: Tephritidae) in Taiwan 【Research report】

臺灣東方果實蠅（Bactrocera dorsalis (Hendel)）(雙翅目：果實蠅科)對殺蟲劑的感受性【研究報告】

Ju-Chun Hsu* and Hai-Tung Feng
許如君*、馮海東

*通訊作者E-mail : juchun@tactri.gov.tw

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Abstract

Toxicity of fenitrothion, fenthion, malathiom, naled, and trichlorfon, to oriental fruit fly (Bactrocera dorsalis (Hendel)) adults was assayed in the laboratory. Chemicals were applied topically to mesonotum of 3- to 5-d-old adults. The LD50 data thus obtained from a laboratory strain when compared with past data revealed that except for trichlorfon, the LD50 for other chemicals were higher by, 1.9 to 4.3 folds. Field strains of fruit flies were collected in Taiwan 1996, and using the past LD90 as the diagnostic dose, and insecticide resistance was assessed. The same test was performed with laboratory strain of the insect. At LD90, only trichlorfon was beyond the upper limits of the confidence intervals, all others were under 50% mortality. In insecticide toxicity assays conducted in 1997 and 1998, on flies collected from around Taiwan, two additional chemicals, formothhion and methomyl, were tested utilizing topical application method. The overall insecticide toxicity in 1998 was some what higher than in 1997, but there was no significant difference between them. The overall insecticide toxicity was significantly higher to insects collected from Hsinbu and Qionglin than to those collected from other investigated locations. At the LD50, fenitrothion, malathion, and trichlorfon were the least toxic and have lost pest control effectiveness at the recommended concentration use in Taiwan. Fenthion and naled were most effective. Effective measures to reduce insecticide resistance selection are needed to sustain the utility of these chemicals in combating oriental fruit flies in Taiwan.

摘要

用三到五日齡的果實蠅成蟲，以局部滴藥法檢測其對已推薦防治藥劑之感受性。所得結果和過去資料比較，室內品系果實蠅對三氯松（trichlorfon）的感受性沒有改變；對乃力松（naled）、芬殺松（fenthion）、撲滅松（fenitrothion）和馬拉松（malathion）之感受性則略為降低（1.9-4.3倍）。1996年在本省24個鄉鎮採集果實蠅，以上述藥劑的LD90為診斷劑量檢測田間棲群之感受性，結果僅三氯松仍維持相同的感受性；為更進一步比較各藥劑的毒性，1997及1998年利用局部滴藥法檢測採自台東、宜蘭、新竹、彰化及高雄等地的果實蠅棲群對上述五種測試藥劑，另加上福木松（formothion）及納乃得（methomyl）的感受性，除新竹地區的果實蠅感受性較高外，其餘地區果實蠅對各藥劑反應差異不顯著；藥劑之間相比，撲滅松、馬拉松和三氯松對果實蠅的毒性低，芬殺松及乃力松的毒性較高。

Key words: Bactrocera dorsalis, insecticides, diagnostic dose, susceptibility.

關鍵詞: 東方果實蠅、殺蟲劑、診斷劑量、感受性

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Insecticide Susceptibility of the Oriental Fruit Fly (*Bactrocera dorsalis* (Hendel))(Diptera: Tephritidae) in Taiwan

Ju-Chun Hsu* and Hai-Tung Feng Taiwan Agricultural Chemicals and Toxic Substances Research Institute, Council of Agriculture, Wufeng, Taichung, Taiwan, R.O.C.

ABSTRACT

Toxicity of fenitrothion, fenthion, malathiom, naled, and trichlorfon, to oriental fruit fly (*Bactrocera dorsalis* (Hendel)) adults was assayed in the laboratory. Chemicals were applied topically to mesonotum of 3- to 5-d-old adults. The LD_{50} data thus obtained from a laboratory strain when compared with past data revealed that except for trichlorfon, the LD_{50} for other chemicals were higher by, 1.9 to 4.3 folds. Field strains of fruit flies were collected in Taiwan 1996, and using the past LD_{90} as the diagnostic dose, and insecticide resistance was assessed. The same test was performed with laboratory strain of the insect. At LD_{90}, only trichlorfon was beyond the upper limits of the confidence intervals, all others were under 50% mortality. In insecticide toxicity assays conducted in 1997 and 1998, on flies collected from around Taiwan, two additional chemicals, formothhion and methomyl, were tested utilizing topical application method. The overall insecticide toxicity in 1998 was some what higher than in 1997, but there was no significant difference between them. The overall insecticide toxicity was significantly higher to insects collected from Hsinbu and Qionglin than to those collected from other investigated locations. At the LD_{50}, fenitrothion, malathion, and trichlorfon were the least toxic and have lost pest control effectiveness at the recommended concentration use in Taiwan. Fenthion and naled were most effective. Effective measures to reduce insecticide resistance selection are needed to sustain the utility of these chemicals in combating oriental fruit flies in Taiwan.

Key words: *Bactrocera dorsalis*, insecticides, diagnostic dose, susceptibility.

Introduction

The oriental fruit fly *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) is the most serious pest of fruits in Taiwan. Its damage to fruit trees reaches 180,000 ha every year. The government-sponsored control program which utilizes insecticide-baited methyl eugenol for male annihilation spends over 60 million New Taiwan dollars annually since early 1980s. Other control methods are recommended to the farmers, however, insecticide is the essential component in all of them. These

*Correspondence address
e-mail:juchun@tactri.gov.tw

include spot application of insecticide-baited protein hydrolyzate or direct spray of insecticides on fruit trees. Table 1 lists the application rate of the commonly used insecticides (PDAF, 1998).

Studies in Hawaii (Keiser, 1989) showed that malation was more toxic to oriental fruit fly in 1967 than 1957, indicating there by absence of resistance to malation in the fruit fly during 10 yr of observation. Theoretically, insecticide use will eventually result in insecticide resistance. However, with few studies conducted so far, there were no indications of resistance in fruit flies (Keiser 1989). Since resistance in the fly will be detrimental to combat the pest in Taiwan, we investigated the susceptibility of the local fruit flies collected from several locations in Taiwan. For routine monitoring for early detection of resistance in a natural population of fruit fly, it is necessary to establish reliable base-line data for susceptible strains and to use a diagnostic dose to enable one to reduce sample size (Georghiou and Mellon 1983).

Materials and Methods

Laboratory colonies Oriental fruit flies were collected from central Taiwan in 1992. Colonies were reared as described by Qiu (1978). All populations were held in a room maintained at 22-28°C with a 12:12 (L:D) photoperiod. The newly emerged adults were placed, 500 to 2000 flies per 39(L)×19(W)×16(H) cm screen cages and provided with water and a standard laboratory diet consisting of a mixture of 4 parts granulated sugar to 1 part peptone (Kyokuto Seiyaku). Three- to 5-d-old adults were used for bioassay.

Field collected flies Larvae from infested fruit namely, guava, carambola, mango, peach, and wax apple, were collected from different locations (Table 2) and were reared separately. The emerged adults were kept in screen cages. Three- to 5-d-old adults were used for bioassay.

Topical application Toxicity of seven insecticides: fenitrothion, fenthion, formothion, malathion, methomyl, naled, and trichlorfon, was evaluated. All insecticides except formothion, were analytical grade (with purities ≥ 96%). The purity of technical grade formothion obtained from BASF, was 70%. Insecticides were dissolved in acetone. Insecticide solution (1μL) was applied to the thoracic tergum of carbon dioxide-anesthetized adult flies. Busvine (1980) indicated the CO_2 anaesthetization should be kept within 7 minutes to avoid harmful effects, so the CO_2 anaesthetization was kept accordingly and a control batch (topical application with acetone only) was finally tested to confirm any harmful effects. After treatment, the flies were transferred to 250mL ice cream cups and fed with a few drops of liquid food (sugar, yeast, and water, 4:1:5) soaked in a small piece of cotton wool. All treated flies were maintained for 24 h at 24±2°C and

Table 1. The commonly used insecticides to control of fruit fly in Taiwan

Insecticide	Application rate (ai Kg/ha)	Remarks
90% methyleugenol + 5% naled	8 mL in 4×4×0.9 cm^3 fiberboard (3 fiberboard per ha)	Methyl eugenol bait
20% malathion	0.16	Spot application with protein hydrolyzate bait
80% trichlorfon	0.1	
40% fenitrothion	0.2	
50% fenthion	0.2	
50% fenthion	0.4 - 0.8	Direct spray on tree
33% formothion	0.66	

Table 2. Collection of fruit flies by different location, months, and host plants in 1996, 1997, and 1998

Location[1] (Place)	Collection Months	Host fruits [2]	Location	Collection months	Host fruits [2]
1996					
Hengshan	August	W	Shetou	March	G
Juolan	May	P	Tianjung	April, June	G and M
Dongshi	May- June	P, M, and W	Shihu	May- June	G, and M
Hsinshe	May- June	P and M	Gukeng	August	G
Shikang	May- June	P and M	Linna	August	G
Wufeng	April- June	G, M, and P	Meishan	July	C and W
Tsautuen	April, June	G and M	Jungbu	July	G, M, and C
Jungliao	May- June	G and M	Madou	July	C
Jiji	May	G	Dashu	August	G
Shuili	May	G	Yanchao	August	G
Guoshing	May, August	G and G	Ligang	July	C
Yuanlin	May- June	G and M	Yanbu	July	C
1997					
Hsinbu	July	W	Yanchao	August	G
Buyan	March, Sept.	C and G	Taitung City	July	C and G
Sheton	March, Sept.	G	Luodong	July	W
1998					
Qionglin	Sept.	G	Yanchao	August	G
Buyan	March, Sept.	C and G	Chihben	July	C and W
Sheton	March, Sept.	G	Yuanshan	July	G
Yuanlin	Sept.				

[1]Location: Hengshan, Hsinbu, and Qionglin in Hsinchu; Juolan in Miaoli; Dongshi, Hsinshe, Shihgang, and Wufeng in Taichung; Tsautuen, Jungliao, Jiji, Shuili, and Guoshing in Nantou; Yuanlin, Buyan, Shetou, Tianjung, and Shihu in Changhwa; Gukeng, Linna in Yunlin; Meishan, Jungbu in Chiayi; Madou in Tainan; Dashu, Yanchao in Kaohsiung; Ligang, Yanbu in Pingtung; Taitung City and Chihben in Taitung; Luodong and Yuanshan in Ilan. (see Fig. 1)

[2]Host fruits: C means Carambola; G means Guavas; M means Mangos; P means Peaches; W means Wax apples.

12:12 (D:L) photoperiod before mortality counts were made.

Diagnostic dose test We chose the dose which may cause 90% mortality to susceptible flies as the diagnostic dose to detect resistance. The LD_{90}s for fenthion, fenitrothion, malathion, naled, and trichlorfon were chosen from past data (Keiser *et al*., 1973). The mortality in the control of under 10% was considered as ideal. Samples of at least 100 (10 batches of 10 each) were used. Extra flies were used to test the LD_{50} of fenthion.

To detect the appearance of insecticide resistance, the insect mortalities at respective diagnostic dosages for five insecticides were compared individually with 90% mortality by using Sign test (Statsoft 1995). Insect mortality with these chemicals was also compared with each other using Wilcoxon match pairs test (Wilcoxon 1945). The diagnostic-dose test was analyzed by Kruskal-Wallis ANOVA by rank to determine whether there are any significant differences amongst areas with respect to resistance to five insecticides.

Topical Toxicity During March to September in 1997 and again in 1998, LD_{50} values for seven insecticides, fenitrothion, fenthion, formothion, malathion, methomyl, naled, and trichlorfon, were estab-

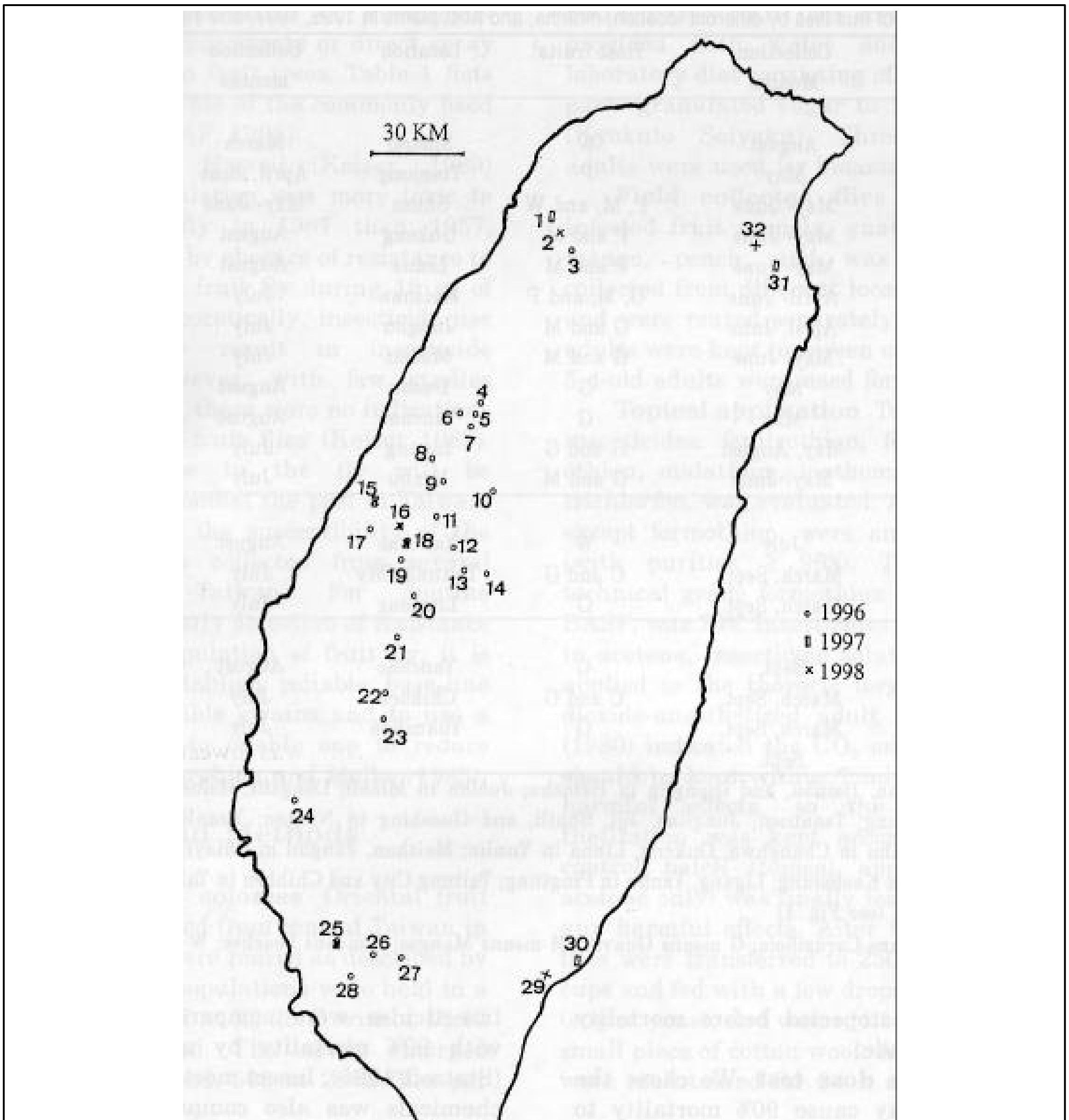

Fig. 1. Map of Taiwan showing the locations of fruit fly collections. 1. Hsinbu; 2. Qionglin; 3. Hengshan; 4. Juolan; 5. Dongshi; 6. Shihgang; 7. Hsinshe; 8. Taichung City; 9. Wufeng; 10. Guoshing; 11. Tsautuen; 12. Jungliao; 13. Jiji 14. Shuili; 15. Buyan; 16.Yuanlin; 17. Shihu; 18. Shetou; 19. Tianjung; 20. Linna; 21. Gukeng; 22. Meishan; 23. Jungbu; 24. Madou; 25. Yanchao; 26. Ligang; 27. Yanbu; 28. Dashu; 29. Chihben; 30. Taitung City; 31. Luodong 32. Yuanshan.

Table 3. Toxicity of five insecticides to laboratory strain of oriental fruit fly

Insecticide	LD_{50} (95% fiducial limits) (ng / fly)	slope
Fenitrothion	60 (52-68)	3.5
Fenthion	12 (11-14)	5.2
Malathion	112 (86-137)	5.0
Naled	15 (14-17)	6.7
Trichlorfon	161 (143-179)	4.4

lished for each sampling place. The insecticide testing and data analysis methods were as described above for topical application.

Comparisons of individual insecticide toxicity in the same area for two years were made by examination of the slopes of the respective probit regression lines and LD_{50} values (Mason and Johnson 1987). For comparing overall insecticide toxicity between time and between areas, the toxicity data of 7 insecticides, including LD_{50} values and their 95% confidence limits, were transported as $Log_{10}(X)$ and analyzed using multifactor analysis of variance (MANOVA) and with of least significant difference (LSD) test, to know which areas are particularly different from other (Statsoft 1995).

Results

The toxicity of five insecticides to laboratory strain is presented in Table 3. The fiducial limits of LD_{50} of insecticides did not overlap. The slopes of the respective probit regression were steep for all insecticides except fenitrothion.

Table 4 lists the response of the fruit fly from different locations to the diagnostic dose of 5 insecticides. Only trichlorfon did not show any insecticide resistance ($Z_{1, 23}$ = 1.67, $P > 0.05$, Sign test). When insect mortality for five insecticides was compared with each other by using Wilcoxon match pairs test, there were significant differences between them except fenitrothion and naled (T = 58, $Z_{1, 24}$ = 1.20, P = 0.23). Trichlorfon treatment showed the same or greater mortality in insects collected from around the island except at Hsinshe, Shikang, Shetou, and Shihu. Fenitrothion, malathion, and naled exceeded the 90% mortality expectation. The response of fenthion was variable, but the mortality at the diagnostic dose was similar only at Hengshan and Jungliao. The northern most location in this investigation, Hengshan, had the highest mortality at the diagnostic dose for all chemicals except trichlorfon. Though each location had some variations in responses to the tested insecticides, there were overall no significant differences between areas (Kruskal-Wallis ANOVA, $H = 7.88 < X^2_{0.05, 23} = 35.17$).

The insecticide toxicity by topical test was significantly negatively correlated with the insect mortality by diagnostic dose test of fruit fly (r = -0.90, df = 7, $P < 0.05$). The highest toxicity of fenthion at the diagnostic dose was at Hengshan where the LD_{50} was lowest (Table 5). When the LD_{50} ratio of field strains to laboratory strain was 2, the mortality of the diagnostic dose was reduced from 96% to 54%. All field strains were more heterogeneous than the laboratory strain and showed lower toxicity reactions except Hengshan strain.

Table 6 lists toxicity to fruit flies of 7 pesticides in different locations in our 1997 and 1998 collection. When g was smaller than 0.4, the 95% fiducal limits were accepted. The 95% fiducial limits of LD_{50} for 1997 and 1998 did not overlap. The LD_{50} of naled being smaller than 30 ng/ fly indicated that it was the most toxic pesticide among the tested chemicals. The second-most toxic one was fenthion, but its toxicity for all locations did not overlap except in Changhwa location. Formothion showed the greatest variance among the locations. The highest toxicity was at Hsinchu location, and the lowest at Yanchao, with a 5.9-fold difference between them in 1998. The slopes of the probit

Table 4. Efficacy of diagnostic dose (LD_{90}) of tested against oriental fruit flies collected from different locations in Taiwan.

Location	Mortality (%)				
	Insecticide (diagnostic dose ng/fly)				
	Fenitrothion (27)	Fenthion (45)	Malathion (77)	Naled (14)	Trichlorfon (480)
Hengshan	18**	93	68**	18**	96*
Juolan	1**	55**	8**	5**	86
Dongshi	4**	74**	23**	1**	97*
Hsinshe	5**	55**	9**	3**	84*
Shikang	2**	66**	17**	12**	84*
Wufeng	7**	76**	31**	3**	92
Tsautuen	12**	67**	9**	5**	90
Jungliao	5**	86	20**	5**	96*
Jiji	4**	85**	20**	4**	91
Shuili	3**	77**	15**	7**	88
Guoshing	1**	52**	18**	2**	87
Yuanlin	2**	62**	16**	3**	94
Shetou	6**	56**	15**	16**	84*
Tianjung	5**	81**	17**	9**	90
Shihu	4**	46**	17**	7**	73*
Gukeng	2**	54**	9**	2**	98**
Linna	0**	58**	15**	0**	99**
Meishan	4**	55**	12**	4**	99**
Jungbu	9**	67**	23**	11**	99**
Madou	6**	64**	28**	6**	100**
Dashu	4**	59**	20**	7**	99**
Yanchao	2**	46**	3**	2**	99**
Ligang	6**	19**	2**	0**	99**
Yanbu	5**	34**	10**	7**	93
Laboratory Strain	13**	96**	34**	6**	96*

Mortality followed by *, ** are significantly different from 90% at $P < 0.05$, 0.01, respectively (Chi square test).

Table 5. Toxicity of fenthion to oriental fruit fly from different locations in comparison with laboratory strain in 1996

Location	Probit regression parameters		Mortality under 45 ng/fly Diagnostic dose (%)	Ratio [2]
	Slope±SEM	LD_{50} (95% fiducial limits) (ng / fly)		
Laboratory strain	5.16±0.70	12 (11-14)	96	1
Hengshan	3.20±0.24	10 (8-11)	93	0.8
Gukeng	3.98±0.24	29 (27-31)	54	2.4
Linna	3.82±0.23	29 (28-31)	58	2.4
Jungbu	4.16±0.40	18 (15-20)	67	1.5
Madou	3.64±0.30	17 (15-18)	64	1.4
Dashu	3.71±0.26	25 (23-28)	59	2.1

[1]Ratio = (LD_{50}, field strain) / (LD_{50}, laboratory strain)

Table 6. Susceptibility of field strain of oriental fruit fly to fenitrothion, fenthion, formothion, malathion, methomyl, naled, and trichlorfon, 1997 and 1998 results

1997			1998		
Insecticide Location	Probit regression parameters		Location	Probit regression parameters	
	Slope±SEM	LD_{50} (95% fiducial limits) (ng / fly)		Slope±SEM	LD_{50} (95% fiducial limits) (ng / fly)
(A) Fenitrothion					
Hsinbu	3.10±0.42	100 (84-116)	Qionglin	3.20±0.35	66 (56-78)
Buyan, Sheton	2.33±0.16	267 (186-362)	Buyan, Sheton, Yuanlin	1.99±0.08	243 (187-311)
Yanchao	2.81±0.29	335 (289-383)	Yanchao	2.70±0.20	393 (305-515)
Taitung City	2.64±0.46	258 (162-341)	Chihben	3.27±0.33	247 (211-289)
Ilan	2.56±0.40	474 (382-620)	Yuanshan	3.53±0.39	372 (320-432)
(B) Fenthion					
Hsinbu	3.79±0.43	17 (15-19)	Qionglin	3.35±0.27	13 (10-15)
Buyan, Sheton	3.10±0.24	33 (24-46)	Buyan, Sheton, Yuanlin	2.73±0.11	35 (29-40)
Yanchao	3.33±0.37	43 (38-48)	Yanchao	2.96±0.28	63 (48-79)
Taitung City	2.02±0.28	35 (26-47)	Chihben	2.55±0.24	55 (47-65)
Ilan	2.67±0.53	36 (26-45)	Yuanshan	3.47±0.35	66 (55-76)
(C) Formothion					
Hsinbu	2.84±0.32	28 (24-34)	Qionglin	4.01±0.44	25 (22-29)
Buyan, Sheton	2.02±0.15	80 (54-126)	Buyan, Sheton, Yuanlin	2.18±0.10	86 (63-110)
Yanchao	2.79±0.21	105 (91-120)	Yanchao	2.82±0.21	147 (119-184)
Taitung City	1.96±0.18	47 (39-57)	Chihben	2.78±0.36	100 (65-138)
Ilan	1.89±0.28	100 (77-147)	Yuanshan	2.60±0.17	130 (108-156)
(D) Malathion					
Hsinbu	3.28±0.37	95 (60-140)	Qionglin	2.63±0.17	119 (101-141)
Buyan, Sheton	2.04±0.19	347 (251-476)	Buyan, Sheton, Yuanlin	1.63±0.08	498 (371-697)
Yanchao	2.53±0.27	386 (330-451)	Yanchao	3.00±0.31	489 (394-598)
Taitung City	2.27±0.24	257 (203-344)	Chihben	4.34±0.52	495 (432-568)
Ilan	2.34±0.25	258 (200-340)	Yuanshan	2.49±0.29	483 (358-604)
(E) Methomyl					
Hsinbu	2.23±0.24	46 (37-57)	Qionglin	2.54±0.19	36 (29-43)
Buyan, Sheton	1.70±0.16	128 (101-164)	Buyan, Sheton, Yuanlin	1.31±0.06	249 (181-375)
Yanchao	2.13±0.22	184 (133-238)	Yanchao	2.17±0.19	171 (130-222)
Taitung City	1.79±0.16	96 (72-132)	Chihben	2.25±0.19	115 (95-143)
Ilan	1.99±0.15	79 (68-93)	Yuanshan	2.17±0.14	118 (86-159)
(F) Naled					
Hsinbu	4.18±0.72	10 (8-12)	Qionglin	5.21±0.49	8 (7-9)
Buyan, Sheton	3.72±0.23	21 (17-25)	Buyan, Sheton, Yuanlin	1.90±0.09	31 (22-44)
Yanchao	5.04±0.43	15 (13-18)	Yanchao	4.12±0.35	22 (18-26)
Taitung City	4.56±0.58	14 (12-16)	Chihben	3.33±0.26	16 (11-21)
Ilan	4.23±0.70	14 (12-17)	Yuanshan	4.82±0.45	21 (18-24)
(G) Trichlorfon					
Hsinbu	4.22±0.61	119 (100-139)	Qionglin	3.07±0.30	86 (66-111)
Buyan, Sheton	2.98±0.25	178 (121-240)	Buyan, Sheton, Yuanlin	3.09±0.14	251 (211-291)
Yanchao	3.25±0.32	167 (128-221)	Yanchao	3.31±0.33	174 (127-237)
Taitung City	3.36±0.47	196 (94-266)	Chihben	3.35±0.34	218 (150-292)
Ilan	3.34±0.33	199 (155-262)	Yuanshan	3.73±0.39	358 (236-482)

regression lines varied in our test. Methomyl had the least slope while naled had the steepest.

The overall insecticide toxicity in 1998 was some what higher than in 1997, but there was no significant difference between them ($F_{1, 200}$ = 2.93, $P > 0.09$, MANOVA test). Areas significantly influenced insecticide toxicity in our investigation ($F_{4, 200}$ = 10.04, $P < 0.05$, MANOVA test). Only the overall insecticide toxicity at Hsinbu and Qionglin was significantly different than the other locations ($P < 0.05$, LSD test).

Discussion

The oriental fruit fly is an exotic insect, but it has survived for a long time in Taiwan. In Taiwan, TARI (1972) tested 6 insecticides against 7-d-old fruit fly adults and used 4 h post-treatment period to record insect mortality. The LD_{50} in their tests was as fellow: fenthion (0.0109), naled (0.019), fenitrothion (0.036), salithion (0.098), malathion (0.100) and trichlorfon (0.240 µg/fly). We used TARI's method, but 4 h post-treatment observation was not enough especially against methomyl. When flies were tested for methomyl toxicity, insect remained quiescent for 4 h post-treatment but recovered after 24 h. Therefore, we used FAO's standardized test method. Keiser *et al*. in Hawaii tested 73 insecticides against this insect in 1973, and results of their research which utilized the standardized test method, was the only information to serve as a base line for determining insecticide susceptibility of oriental fruit fly from Taiwan. The order of toxicity of insecticides tested in our work was the same as TARI's (1972), although both tests used different methods. There are differences between our results and those of Keiser *et al.* (1973) data.

The comparative toxicity of the insecticides to laboratory strain and field strain was similar. Using a diagnostic dose to detect the appearance of resistance could be effective in reducing the sample size. However, when the results of diagnostic-dose test reveal extreme low or extreme high mortalities, it is hard to compare the insecticide resistance between chemicals or areas. Much low mortality would indicate need to confirm insecticide toxicity again before comparison could be made. The 90% diagnostic dose test could replace the topical application method, if the samples were not enough to do the topical application test and the result of diagnostic-dose were not with extreme mortality.

There is no direct correlation between the lethal dose by using topical method and the lethal concentration by using contact or feeding assay. Keiser (1989) showed that malathion applied to the thoracic mesonotum was about 2 times as effective as when applied orally at the LD_{50}, and at the LD_{95} the differences were even more pronounced. For representing actual field condition, it is necessary to do feeding assay for fruit fly. This fact needs to be taken into consideration by PDAF in their oriental fruit fly control program.

It is worth noting the speed of resistance development in the fruit fly as seen from the steep slope. Owing to the distance between the confidence intervals, Keiser (1989) emphasized the importance of the LD_{95} in evaluating the development of resistance in fruit flies. Our results are similar. A small change in the LD_{50} results in a much greater change in mortality. Measures to reduce the speed of resistance development, especially for the fruit fly, are urgently needed.

Keiser (1989) indicated absence of resistance to malathion in the fruit fly during 25 yr of observation. We, however, found differences in effectiveness of malathion between our investigation sites. At the LD_{50}-level, there were 5-fold differences between Hsinchu and Shetou or Kaohsiung in 1997 and 1998. The laboratory strain used in our study in 1996 had an LD_{50} 3 times greater than the strain used by Keiser (Table 3). The resistance to malathion in field strains of fruit flies in Taiwan need further research.

All tested insecticides are organophosphates, but the response of the fruit fly is variable. Keiser (1968) pointed out that fenthion was the most effective; malathion, though effective in dry periods, was subject to loss of toxicity due to rainfall; trichlorfon and naled were among the compounds having poor residual effectiveness in comparisons with mortalities obtained with 37 other insecticides after 1, 2, 4, 8, and 16 d of weathering. The poor residual effectiveness could explain the slow increase in resistance to trichlorfon and naled. In our study, fenthion was the most toxic among 5 compounds to laboratory strain, but it was not the most toxic in the field investigation in 1997 and 1998. Although naled still had a low LD_{50}, however, frequent applications of this insecticide is required to maintain the effectiveness possibly because of its rapid decomposition. We need a more active strategy to reduce rate of development of resistance to organophosphates in the fruit fly.

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臺灣東方果實蠅（*Bactrocera dorsalis* (Hendel)）(雙翅目：果實蠅科)對殺蟲劑的感受性

許如君* 馮海東 行政院農委會農業藥物毒物試驗所

摘　要

用三到五日齡的果實蠅成蟲，以局部滴藥法檢測其對已推薦防治藥劑之感受性。所得結果和過去資料比較，室內品系果實蠅對三氯松（trichlorfon）的感受性沒有改變；對乃力松（naled)、芬殺松（fenthion）、撲滅松（fenitrothion）和馬拉松（malathion）之感受性則略為降低（1.9-4.3倍）。1996年在本省24個鄉鎮採集果實蠅，以上述藥劑的LD_{90}為診斷劑量檢測田間棲群之感受性，結果僅三氯松仍維持相同的感受性；為更進一步比較各藥劑的毒性，1997及1998年利用局部滴藥法檢測採自台東、宜蘭、新竹、彰化及高雄等地的果實蠅棲群對上述五種測試藥劑，另加上福木松（formothion）及納乃得（methomyl）的感受性，除新竹地區的果實蠅感受性較高外，其餘地區果實蠅對各藥劑反應差異不顯著；藥劑之間相比，撲滅松、馬拉松和三氯松對果實蠅的毒性低，芬殺松及乃力松的毒性較高。

關鍵詞：東方果實蠅、殺蟲劑、診斷劑量、感受性。