INSECTICIDE RESISTANCE IN *BLATTELLA GERMANICA* (L.) (DICTYOPTERA: BLATTELLIDAE) FROM HOTELS AND RESTAURANTS IN MALAYSIA

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Abstract - Twenty three strains of field populations of the German cockroach, *Blattella germanica* (L.) collected from hotels and restaurants from various localities in peninsular Malaysia were tested for their susceptibility to commonly used insecticides (propoxur, bendiocarb, chlorpyrifos, fenitrothion, pirimiphos-methyl, cypermethrin, permethrin and deltamethrin) using a modified W.H.O. tarsal contact method at a standard concentration of 20 mg cm^{-2}. Several strains were also tested against other insecticides (DDT, endosulfan, dieldrin, diazinon, chlorpyrifos-methyl, malathion, carbaryl, etofenprox, bifenthrin and acetamiprid). Susceptibility to hydramethylnon was evaluated using commercial baits with a feeding bioassay method. Low to high levels of resistance to carbamates were detected (1.8 – 65.2X) while resistance to organophosphates was low (1.1 – 4.3X). However, one strain demonstrated high resistance to malathion (>275X). Resistance to pyrethroids ranged from 1.1 – 17.6X. Eleven strains tested showed low to high resistance to DDT (1.3 – 40.7X). No resistance to hydramethylnon-based baits was detected in this study (≤1.3X). Several strains were chosen for synergism studies using piperonyl butoxide (PBO) and *S,S,S*-tributylphosphorotrithioate (DEF). Resistance to carbamates was partially suppressed by PBO and DEF, suggesting possible involvement of monooxygenase and esterase in the resistance. However, organophosphate resistance was only negated by DEF. Resistance to pyrethroids in several strains which also demonstrated DDT resistance, was not suppressed by both PBO and DEF, indicating possible involvement of a non-metabolic resistance mechanism.

Key words - Insecticide resistance, *Blattella germanica*, hotels, restaurants

INTRODUCTION

The German cockroach, *Blattella germanica* (L.) is a major urban insect pest in many parts of the world. In Malaysia, it is the main insect pest in hotels, restaurants and other food outlets (Yap *et al.*, 1991; Lee *et al.*, 1993). They are not readily found in Malaysian households; however, during the last two years, we have began to trap German cockroaches in urban apartments in major cities in Malaysia (CY Lee, unpublished data).

As in the past, control of this species presently continues to rely heavily on the use of insecticides. Extensive usage of insecticides has led to the development of insecticide resistance in this species (Lee, 1997). Since resistance to chlordane in the German cockroach was first reported in 1952 in Corpus Christi, Texas, USA (Heal *et al.*, 1953), many other cases have been documented throughout USA (Bennett and Spink, 1968; Cochran, 1989; Rust and Reierson, 1991; Zhai and Robinson, 1991; Hemingway *et al.*, 1993a; 1993b; Scharf *et al.*, 1996) and Europe (Chapman *et al.*, 1993; Vagn-Jensen, 1993). A review of the cases of insecticide resistance in the German cockroach reported from 1953 – 1997 had been published recently (Lee, 1997). Despite it being an important insect pest in Asia, reports on cases of insecticide resistance in field German cockroach in this region had previously been limited to studies from Japan, i.e. those prior to the 1990s (Yasutomi *et al.*, 1966; Umeda *et al.*, 1988). In Malaysia, the first case of insecticide resistance in the German cockroach was reported by Lee *et al.* (1996a) where twelve field strains (collected between 1993 – 1995) showed low to high resistance to carbamates, low resistance to organophosphate and low to moderate resistance to pyrethroid insecticides. All strains reported showed control failure by carbamate insecticides under field condition. Subsequently, more cases of German cockroach resistance from this region have also been documented (Lee *et al.*, 1997a; 1997b; Lee, 1998; Lee and Lee, 1998). During the past two years, many complaints were received from Malaysian pest control operators who began to report control failure with pyrethroid insecticides. This prompted us to conduct this current study. This paper summarizes some of the results

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of our insecticide resistance monitoring programme on the German cockroach from 1996 – 1998. Twenty three field populations were collected from various locations in Peninsular Malaysia and their resistance profiles to novel and conventional insecticides were characterized. Possible involvement of monooxygenase and esterase in these strains was also determined with synergism studies.

MATERIALS AND METHODS

Cockroach strains

Field populations of the German cockroaches were collected by placing baited glass jars for 24 – – 48 hours in food preparation areas. Each trap was baited with a piece of white bread, pre-soaked with local beer. Upon collection, the cockroaches were brought back to the laboratory and reared for 2 – 3 generations to achieve enough numbers for testing, under environmental conditions of 26 ± 2 ºC and 70 ± 5% relative humidity. The history of these strains is presented in Table 1. An insecticide-susceptible strain (ICI) was used as a standard for comparison. All cockroaches used in this study were 7 – 21 days in age.

Table 1. Malaysian field collected German cockroach strains tested in this study

Strain	Premises	Location	Year of collection
HH	Cafeteria	Georgetown, Penang	1996
CS	Cafeteria	Georgetown, Penang	1996
BA	Restaurant	Georgetown, Penang	1996
AK	Restaurant	Georgetown, Penang	1996
WT	Cafeteria	Georgetown, Penang	1996
HT	Food court	Kuala Lumpur	1996
ML2	Hotel kitchen	Kuala Lumpur	1996
CP	Restaurant	Kuala Lumpur	1996
GS	Hotel kitchen	Batu Feringgi, Penang	1996
TSS	Restaurant	Kuala Lumpur	1996
ML6	Hotel	Kuala Lumpur	1996
ML11	Hotel	Kuala Lumpur	1997
ML11X	Hotel	Kuala Lumpur	1997
LHFA	Restaurant	Kuala Lumpur	1997
LHFB	Restaurant	Kuala Lumpur	1998
SWY	Hotel kitchen	Georgetown, Penang	1998
HRP	Univ. cafeteria	Minden, Penang	1998
BKT	Univ. cafeteria	Minden, Penang	1998
KK	Restaurant	Muar, Johor	1996
AT	Restaurant	Muar, Johor	1997
MKL	Restaurant	Melaka	1996
PPL	Restaurant	Taiping, Perak	1997
SK	Restaurant	Seremban, Negeri Sembilan	1997

Chemicals

Technical grade insecticides used for baseline susceptibility tests and synergism studies were as follow: propoxur (99.5%), bendiocarb (95.0%), carbaryl (99.9%), chlopyrifos (97.4%), fenitrothion (96.6%), pirimiphos-methyl (96.1%), diazinon (98.6%), chlorpyrifos-methyl (96.8%), malathion (92.8%), cypermethrin (94.5%), permethrin (94.2%), deltamethrin (99.8%), etofenprox (96.3%), bifenthrin (98.5%), DDT (>98%), endosulfan (95.1%) and dieldrin (90.0%). All technical grade insecticides were diluted in analytical grade acetone. For acetamiprid, a 3% EC formulation was used. For test on hydramethylnon, a commercial bait product (Combat®) containing 1.65% hydramethylnon was purchased from a local supermarket. The two synergists used in this study were piperonyl butoxide (PBO) (99.0%), a monooxygenase inhibitor and *S,S,S*-tributylphosphorotrithioate (DEF) (98.3%),

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a hydrolase inhibitor. All insecticides and synergists used were diluted in analytical grade acetone, except for acetamiprid (diluted in water) and the hydramethylnon baits.

WHO tarsal-contact susceptibility test

The tarsal contact susceptibility test adopted in this study was a modification of the W.H.O. glass jar method (World Health Organization, 1975) and as reported in Lee (1998). Generally, ten adult males were introduced into a 0.45 liter glass jar, pre-coated earlier on its inner base surface with 20 mg cm^{-2} of insecticide. The whole inner surface (except the base) was smeared with a thin layer of petroleum jelly to prevent cockroaches from escaping. Knockdown of the cockroaches was recorded at selected time intervals. For synergism studies, cockroaches were topically treated (Lee *et al.*, 1996a; 1998) with 100 mg of PBO or 30 mg of DEF, or both together, approximately 2 hours prior to insecticide susceptibility tests. All experiments were replicated 3–6 times.

Feeding bioassay for hydramethylnon bait

Feeding bioassay followed the procedures as described in Lee (1998). Generally, tests were conducted in arenas, each measuring 35 x 30 x 10 cm and containing 20 adult males. After 24 hours of acclimatization, a bait station and food were each placed at adjacent corners of the arena, opposite to where the harborage was placed. Water was placed close to the harborage. Mortality of the cockroaches was assessed every 12 hours up to 14 days. Each experiment was replicated 3–5 times and 15 field strains were tested.

Data analyses

Data were pooled and subjected to probit analysis (Robertson and Preisler, 1992) using POLO-PC software program (LeOra Software, 1997). A minimum of six time-response points were used for each analysis. Resistance ratio (RR) was calculated by dividing the LT_{50} value of the resistant strain with the corresponding lethal time of the susceptible strain. An RR_{50} of <2 indicates very little or no presence of resistance, RR_{50} between 2–5 indicates the presence of low resistance which sometime causes control failure, RR_{50} between 5–10 indicates moderate level of resistance and RR_{50} of >10 demonstrates high resistance. Due to the enormous amount of data, only the resistance ratios at LT_{50} (RR_{50}) were presented in this paper. Interested researchers are urged to contact the senior author (CYL) for LT_{50} data and other relevant information.

RESULTS AND DISCUSSION

A total number of 18 insecticides covering six classes (organochlorine, carbamate, organophosphate, pyrethroid, amidinohydrazone and chloronicotinyl) were tested against the ICI susceptible strain (Table 2). Eight insecticides were further chosen and tested in the presence of synergists (PBO and DEF) against this strain.

Carbamate resistance (propoxur and bendiocarb) was prevalent in the field strains collected (Table 3). About 50% of the field strains collected showed RR_{50} of >5 to propoxur. This may reflect the long-term usage of propoxur in this region. Propoxur has been used during the past two decades in Malaysia by pest control operators. Almost all field strains tested were also resistant to bendiocarb, in spite that the chemical has not been used for German cockroach control in Malaysia. Cross resistance within insecticides from similar classes or with similar modes of action is common. A carbaryl-resistant strain from USA had shown cross-resistance to other carbamates (McDonald and Cochran, 1968). Lee *et al.* (1996) had also demonstrated cross-resistance to bendiocarb in twelve propoxur-resistant strains. A highly bendiocarb-resistant strain collected from Maryland, USA was also resistant to organophosphate insecticides (diazinon, malathion and propoxur) (Nelson and Wood, 1982).

Table 2. Baseline susceptibility of the ICI susceptible strain to various insecticides (with and without the presence of synergists).

Insecticide[1] + synergist	n	Slope ± SE	LT_{50} (95% FL) (mins)	LT_{95} (95% FL) (mins)
endosulfan	120	5.4 ± 0.6	105.4 (99.3 – 111.9)	212.9 (186.9 – 257.3)
dieldrin	120	10.0 ± 1.0	104.4 (100.6 – 108.0)	152.7 (142.9 – 167.9)
+ PBO	120	6.2 ± 0.7	57.5 (54.2 – 60.7)	106.0 (95.1 – 124.3)
+ DEF	120	10.4 ± 1.1	64.4 (62.0 – 67.0)	92.8 (86.2 – 103.3)
+ PBO + DEF	120	8.8 ± 1.1	26.0 (23.8 – 28.0)	40.0 (35.5 – 50.8)
DDT[2]	120	1.4 ± 0.1	230.0 (161.8 – 335.5)	3300 (1700 – 9330)
pirimiphos-methyl	120	9.1 ± 0.9	44.4 (42.7 – 46.1)	67.5 (62.6 – 75.0)
fenitrothion	120	20.2 ± 2.1	31.4 (30.9 – 32.0)	37.9 (36.6 – 39.8)
diazinon	120	6.4 ± 0.6	30.0 (28.4 – 31.5)	54.0 (49.1 – 61.7)
chlorpyrifos	120	15.5 ± 1.6	59.4 (58.0 – 60.7)	75.8 (72.6 – 80.6)
+ PBO	120	10.2 ± 1.0	31.4 (30.2 – 32.5)	45.5 (42.6 – 49.8)
+ DEF	120	7.0 ± 0.9	24.9 (22.4 – 27.9)	42.6 (35.2 – 67.6)
+ PBO + DEF	120	8.9 ± 1.1	21.2 (19.7 – 22.7)	32.6 (29.1 – 40.1)
chlorpyrifos-methyl	120	12.2 ± 1.0	33.3 (32.4 – 34.1)	45.3 (43.3 – 48.2)
malathion	120	4.5 ± 0.6	35.0 (32.1 – 37.9)	81.4 (68.3 – 108.9)
+ PBO	120	6.6 ± 0.8	33.5 (31.1 – 36.1)	59.3 (50.8 – 79.3)
+ DEF	120	10.8 ± 1.4	20.8 (19.9 – 21.7)	29.5 (27.5 – 33.2)
+ PBO + DEF	120	5.9 ± 0.6	26.5 (24.9 – 27.9)	50.5 (45.2 – 59.5)
carbaryl	120	7.9 ± 0.8	93.6 (89.4 – 98.0)	151.0 (137.8 – 172.8)
propoxur	120	14.0 ± 1.6	14.2 (13.7 – 14.6)	18.6 (17.6 – 20.2)
+ PBO	120	4.0 ± 0.5	9.3 (8.2 – 10.6)	24.1 (18.6 – 39.1)
+ DEF	120	15.7 ± 2.8	9.8 (9.4 – 10.2)	12.4 (11.5 – 14.3)
+ PBO + DEF	120	8.4 ± 1.1	11.3 (10.1 – 12.7)	11.3 (10.1 – 12.7)
bendiocarb	120	6.9 ± 0.7	20.6 (18.9 – 22.3)	35.6 (31.1 – 45.2)
+ PBO	120	6.4 ± 0.7	16.3 (15.3 – 17.2)	29.5 (26.6 – 34.2)
+ DEF	120	13.4 ± 1.7	9.2 (8.8 – 9.5)	12.2 (11.4 – 13.4)
+ PBO + DEF	120	8.8 ± 1.0	19.0 (18.0 – 20.0)	29.2 (26.7 – 33.4)
bifenthrin	120	6.3 ± 0.7	14.4 (13.5 – 15.2)	26.2 (23.4 – 31.1)
etofenprox	120	8.4 ± 1.3	7.3 (7.0 – 7.9)	11.7 (10.6 – 13.8)
+ PBO	120	4.0 ± 0.5	6.7 (5.3 – 8.0)	17.2 (12.9 – 34.5)
+ DEF	120	4.8 ± 0.5	6.8 (5.9 – 7.7)	14.9 (12.1 – 21.7)
+ PBO + DEF	120	4.4 ± 0.7	8.2 (7.3 – 9.5)	19.4 (14.5 – 37.1)
permethrin	120	6.9 ± 0.8	8.3 (7.8 – 8.8)	14.4 (12.8 – 17.4)
+ PBO	120	3.3 ± 0.4	5.3 (4.5 – 6.1)	16.6 (12.3 – 29.0)
+ DEF	120	3.4 ± 0.4	5.4 (4.7 – 6.2)	16.5 (12.7 – 25.9)
+ PBO + DEF	120	4.7 ± 0.6	6.8 (6.3 – 7.4)	15.3 (12.9 – 19.8)
deltamethrin	120	10.1 ± 2.2	4.6 (4.2 – 4.9)	6.6 (5.9 – 8.5)
+ PBO	120	5.0 ± 0.8	3.9 (3.0 – 5.1)	8.4 (5.9 – 31.9)
+ DEF	120	4.6 ± 0.6	3.6 (2.9 – 4.2)	8.1 (6.4 – 13.7)
+ PBO + DEF	120	6.2 ± 0.8	4.6 (4.2 – 5.0)	8.4 (7.4 – 10.4)
acetamiprid[3]	120	9.0 ± 0.9	12.0 (11.2 – 12.8)	18.3 (16.6 – 21.5)
hydramethylnon[4]	120	10.9 ± 1.4	1.6 (1.4 – 1.7)	2.2 (2.1 – 2.5)

[1]Technical grade insecticides (unless specified) (diluted in analytical grade acetone) at concentration of 20 mg/cm^2 were used.
[2]Concentration of 60 mg/cm^2 was used.
[3]EC formulation [3%] (diluted in distilled water) at concentration of 20 mg/cm^2 was used.
[4]Bait station containing 1.65% hydramethylnon. LT_{50} values are expressed in day [s].

All field strains (except SWY strain) tested showed RR_{50} of <5 to common organophophate insecticides (chlorpyrifos, fenitrothion and pirimiphos-methyl) (Table 3). In the case of SWY, the premises had been monthly treated with pirimiphos-methyl for the past one year prior to the cockroach collection. From the results obtained, the use of organophosphate insecticides for pest control operation may still provide good control against these populations.

Low to moderate level of resistance were detected for pyrethroid insecticides (Table 3). Except for LHFA and PPL, all field collected strains had RR_{50} of <5 when tested with three pyrethroid candidates. Pyrethroid insecticides (lambda-cyhalothrin, deltamethrin and cyfluthrin) have been used in Malaysia for German cockroach control in the early 1990s when control failure with propoxur was experienced in many premises. Prolonged and continuous usage in most premises may be the cause of the occurrence of pyrethroid resistance.

Resistance to organochlorines (DDT, endosulfan and dieldrin) was moderate to high in the field strains tested (Table 5). Two out of 11 strains tested showed high resistance to DDT, i.e. ML6 and ML11X strains. About 64% of the strains tested for dieldrin showed RR_{50} between 2 – 5. Organochlorine insecticides had not been used in German cockroach pest control operations since two decades ago. Several strains were further chosen and tested against other insecticides (diazinon, chlorpyrifos-methyl, malathion, carbaryl, etofenprox, bifenthrin and acetamiprid) from several insecticide classes (Table 4). Results indicated moderate to high resistance to malathion. Malathion is not commonly used for German cockroach control in Malaysia, and this may indicate another case of cross-resistance from other insecticides, possibly from the carbamates.

No resistance to hydramethylnon was detected in Malaysian field collected strains. All strains showed LT_{50} values comparable to that of the ICI susceptible strain. Hydramethylnon is presently available in containerized and gel formulations for pest control operations in Malaysia. Lee (1998) had demonstrated the potential of using hydramethylnon baits alone against carbamate-resistant German cockroaches in food-outlets in Malaysia. In that study, more than 80% population suppression was achieved in all test premises up to 3 months post-treatment.

Resistance to carbamate insecticides was partially suppressed by PBO or DEF (Table 6), suggesting the involvement of monooxygenase and esterase in these strains. Almost all field collected strains showed propoxur resistance level reduced drastically in the presence of PBO or DEF. In the presence of both synergists together, resistance in most strains was negated, except for HT, CP, LHFA, AT and SK strains. For these latter strains, the results may indicate the involvement of other resistance mechanisms (eg. altered acetylcholinesterase) in carbamate resistance. Earlier, Lee *et al.* (1996b; 1997b) had reported the occurrence of altered acetylcholinesterase in carbamate-resistant strains from Malaysia.

Organophosphate resistance was not suppressible with PBO in the 11 field strains tested (Table 6). In some cases, the resistance level increased with PBO treatment, especially when tested with malathion. This may be due to suppression of oxidative enzymes which are needed for activation of malathion to malaoxon, a more toxic compound. Elevated esterase is suspected to be involved in organophosphate resistance with complete or partial suppression of resistance in the strains tested in the presence of DEF. In four strains tested with malathion, three of them showed drastic reduction of resistance level when DEF was used. A preliminary study executed on HH, WT and LHFA strains to determine whether malathion resistance was negated in the presence of TPP (triphenyl phosphate), a specific carboxylesterase-mediated malathion resistance inhibitor (Hemingway and Georghiou, 1984), showed complete suppression of the resistance. This suggested that malathion resistance in these strains is possibly due to the involvement of carboxylesterase (C.Y. Lee, unpublished).

The three pyrethroid candidates chosen for synergism studies were etofenprox, permethrin and deltamethrin. Results indicated that out of the eight strains tested, only three strains (ML11, LHFA and AT) showed partial permethrin resistance suppression in the presence of PBO (Table 8). The resisance levels in other strains were not affected by synergists. Some of these strains (eg. HT, ML2 and CP) had also earlier showed low level of resistance to DDT (Table 4). This suggested the possible involvement

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Table 3: Resistance profile of field collected Malaysian strains of the German cockroach to some commonly used insecticides using WHO tarsal-contact method at 20 µg/cm²

Strain	Resistance ratio at LT_{50}							
	Carbamates		Organophosphates			Pyrethroids		
	Propoxur	Bendiocarb	Chlorpyrifos	Fenitrothion	Pirimiphos-methyl	Cypermethrin	Permethrin	Deltamethrin
HH	5.6	14.9	1.5	2.1	1.7	1.2	1.8	1.3
CS	1.7	7.6	1.1	1.5	1.3	1.2	1.3	1.1
BA	2.3	6.0	1.9	3.3	3.0	1.3	1.7	1.1
AK	2.2	8.1	2.3	2.9	3.1	1.4	2.3	1.2
WT	9.8	24.7	4.3	4.1	2.9	1.7	2.8	1.9
HT	10.7	11.9	1.7	1.2	1.9	3.6	3.2	2.0
ML2	11.5	13.3	2.3	1.8	2.2	2.2	2.2	1.3
CP	9.8	10.2	1.8	1.6	2.0	1.8	2.1	1.4
GS	8.3	5.1	1.3	1.3	2.1	1.5	1.9	1.2
TSS	5.4	9.0	1.1	1.1	1.7	1.5	2.7	1.2
ML6	1.3	3.1	2.5	2.3	2.0	1.9	2.0	2.1
ML11	3.2	65.2	1.6	2.0	2.7	-	3.8	1.9
ML11X	2.0	5.6	1.4	1.8	2.3	-	1.6	1.4
LHFA	1.8	22.2	2.6	2.1	2.7	-	17.6	1.8
LHFB	-	-	-	1.4	2.3	-	2.2	-
SWY	-	-	-	2.2	7.1	-	-	-
HRP	2.8	-	-	2.3	2.2	-	1.3	1.0
BKT	-	-	-	1.5	-	-	1.4	1.1
KK	3.4	14.5	1.9	2.2	2.1	1.2	1.7	1.1
AT	7.9	19.8	2.5	2.7	2.3	1.9	2.2	1.4
MKL	5.1	16.3	2.1	1.9	2.2	1.3	1.9	1.1
PPL	2.3	10.5	1.6	3.0	2.5	3.5	14.5	2.9
SK	8.8	18.4	2.4	1.8	2.3	1.4	2.0	1.1

Table 4. Resistance profile of field collected Malaysian strains of the German cockroach to other insecticides at 20 µg/cm² using WHO tarsal-contact method.

Strain	Resistance ratio at LT_{50}						
	Diazinon	chlorpyrifos-methyl	malathion	carbaryl	etofenprox	bifenthrin	acetamiprid
HH	2.3	-	23.1	-	1.5	1.3	-
CS	1.3	-	15.9	-	1.2	1.0	-
BA	1.6	-	19.5	-	1.3	1.1	-
AK	2.9	-	-	9.8	1.9	1.4	-
WT	3.7	-	20.1	-	2.0	1.6	-
ML11	1.4	1.1	2.0	2.5	2.0	1.9	2.0
ML11X	1.0	1.0	2.4	4.3	3.1	2.2	2.1
LHFA	1.5	2.9	>275	3.2	3.2	-	1.0
LHFB	-	-	-	-	-	-	1.3
HRP	1.0	-	3.6	-	-	-	1.8
BKT	-	-	-	-	-	-	1.1
SWY	-	1.5	-	-	-	-	2.1

of *kdr*-type resistance in pyrethroid resistance (Dong *et al.*, 1998). Lee *et al.* (1996a) and Lee and Lee (1998) had earlier reported the involvement of *kdr*-type resistance in several strains of German cockroaches from Malaysia. Synergism data for deltamethrin were not conclusive due to the low deltamethrin RR_{50} (without presence of synergists) detected earlier in the tested strains.

Some strains showed increase in RR_{50} values upon treatment with PBO or DEF (Table 7). This does not indicate an antagonistic effect of the synergist. As the RR_{50} value is obtained by diving the LT_{50} of the resistant strain with that of the susceptible strain, the RR_{50} value will increase if there is greater oxidative and hydrolytic activity in the susceptible strain, compared to those in the resistant ones. This had been reported earlier in German cockroaches (Lee *et al.*, 1996a) and house flies (Scott and Georghiou, 1986).

Table 5. Resistance profile of field collected Malaysian strains of the German cockroach to three organoclorine insecticides at 20 mg/cm^2 (except for DDT where 60 mg/cm^2 was used) using WHO tarsal-contact method.

Strain	Resistance ratio at LT_{50}		
	DDT	endosulfan	dieldrin
HT	1.9	-	1.2
ML2	3.2	1.9	1.9
CP	1.6	-	3.0
GS	1.4	2.2	2.1
TSS	1.3	-	2.0
ML6	40.7	-	2.8
ML11X	21.9	1.6	2.2
ML11	-	1.5	2.2
LHFA	-	2.0	2.3
LHFB	-	2.5	3.6
SWY	1.7	-	4.4
HRP	8.7	1.1	1.6
KK	1.4	-	1.3
AT	1.5	-	1.6

Cochran (1997) recently reported that the insecticidal concentration used in the glass jar will affect the level of resistance detected. According to the author, excessive high levels of insecticide used will mask resistance. The low resistance level to pyrethroid insecticides shown in this study was due to the above factor. Our preliminary study confirmed Cochran's earlier findings. Using LC_{95} concentration of deltamethrin (= 0.06 mg/cm^2) obtained from dose-response bioassay against ICI susceptible strain as the discriminating concentration (DC), we tested the insecticide against two field strains (LHFA and ML11) and compared the resistance ratios obtained with those obtained earlier with deltamethrin at concentration of 20 mg/cm^2. A higher deltamethrin resistance levels was recorded for the two strains tested (Table 8). However, the problem associated with testing using DC is that in some cases, it may take a long time ranging from 24 hours to almost 5 days to complete a bioassay test (especially on a highly resistant strain). Thus despite its sensitivity in detecting resistance, the use of DC may not be practical in certain cases. A possible solution to the above problem may be the use of a mid-way concentration of 10 times the DC.

In conjuction with the nationwide resistance monitoring program, several German cockroach resistance management options have been proposed to the Malaysian pest control operators, namely, insecticide rotation, mixture (pyrethroid-IGR) and baiting. To date, many of them have started adopting insecticide rotation strategy in their control operation although the awareness level is still not satisfactory. Pyrethroid-IGR mixture is hardly used by Malaysian pest control operators due the high cost incurred when using two separately formulated products and problem associated with mixing of the two chemicals. It is anticipated that a pre-mixed pyrethroid-IGR formulation will be preferred by most pest control

Table 6. Resistance profile of field collected Malaysian strains of the German cockroach to carbamate and organophosphate insecticides at 20 mg/cm^2 upon treatment with PBO and DEF, using tarsal-contact method.

Strain	Resistance ratio at LT_{50}			
	Organophosphate		Carbamate	
	chlorpyrifos (alone) + PBO + DEF + PBO + DEF	malathion (alone) + PBO + DEF + PBO + DEF	propoxur (alone) + PBO + DEF + PBO + DEF	bendiocarb (alone) + PBO + DEF + PBO + DEF
HH	1.5	23.1	5.6	14.9
	1.6	35.0	1.9	3.4
	1.2	2.6	1.7	2.7
	1.2	2.2	1.4	1.3
AK	2.3	-	2.2	8.1
	2.0	-	1.2	1.9
	1.5	-	1.3	1.6
	1.3	-	1.2	1.2
WT	4.3	20.1	9.8	24.7
	4.3	24.0	2.3	3.2
	1.2	1.7	3.3	2.9
	1.4	2.1	1.3	1.2
HT	1.7	-	10.7	11.9
	2.0	-	1.9	2.5
	1.2	-	2.1	3.4
	1.1	-	1.5	1.5
ML2	2.3	-	11.5	13.3
	1.5	-	2.4	3.5
	1.3	-	1.8	2.4
	1.3	-	1.4	1.7
CP	1.8	-	9.8	10.2
	1.8	-	3.8	2.3
	1.1	-	2.2	1.7
	1.4	-	1.9	1.2
ML11	1.6	2.0	3.2	65.2
	1.6	1.7	2.1	1.8
	1.5	1.6	1.7	2.0
	1.9	1.1	1.2	1.3
LHFA	2.6	>275	1.8	22.2
	1.7	3.7	2.1	1.8
	1.8	2.0	1.5	1.8
	2.5	2.0	1.9	1.8
AT	2.5	-	7.9	19.8
	1.9	-	2.2	2.7
	1.3	-	1.8	3.0
	1.3	-	1.4	1.9
MKL	2.1	-	5.1	16.3
	2.0	-	2.2	1.8
	1.4	-	1.9	1.6
	1.2	-	1.3	1.1
SK	2.4	-	8.8	18.4
	2.2	-	1.7	2.1
	1.4	-	2.0	4.2
	1.9	-	1.5	1.8

Table 7. Resistance profile of field collected Malaysian strains of the German cockroach to pyrethroid and cyclodiene insecticides at 20 mg/cm^2 upon treatment with PBO and DEF, using tarsal-contact method.

Strain	Resistance ratio at LT_{50}			
	Pyrethroid			Cyclodiene
	etofenprox + PBO + DEF + PBO + DEF	permethrin + PBO + DEF + PBO + DEF	deltamethrin + PBO + DEF + PBO + DEF	dieldrin + PBO + DEF + PBO + DEF
WT	-	2.8	1.9	-
	-	3.0	1.8	-
	-	3.2	2.0	-
	-	2.2	1.7	-
HT	-	3.2	2.0	-
	-	3.4	1.8	-
	-	3.2	1.7	-
	-	3.5	1.5	-
CP	-	2.1	1.4	-
	-	2.0	1.3	-
	-	2.3	1.4	-
	-	1.8	1.4	-
ML2	-	2.2	1.3	1.9
	-	1.9	1.2	1.8
	-	2.0	1.3	1.7
	-	2.2	1.3	1.8
ML11	2.0	3.8	1.9	2.2
	2.7	1.9	1.7	2.1
	2.6	2.5	1.7	1.5
	1.4	1.0	1.5	1.9
LHFA	3.2	17.6	1.8	2.3
	2.6	3.8	1.6	2.1
	1.6	2.4	1.8	1.6
	1.1	2.1	1.5	2.1
AT	-	2.2	1.4	1.6
	-	1.7	1.4	1.5
	-	1.8	1.4	1.6
	-	1.3	1.5	1.3
PPL	-	14.5	2.9	-
	-	16.7	2.2	-
	-	14.6	2.3	-
	-	15.0	2.4	-

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operators. Baiting is still a fairly new concept to the Malaysian pest operators, despite the fact that professional gel bait has been introduced into the country for a year now. Many pest control operators are still skeptical about this concept and often treat baiting as a supplementary treatment to residual sprays, although several studies had shown that baiting can serve as a stand-alone mode of control (Lee, 1998). There is a serious need to educate the pest control operators about the proper control strategies in this region.

Table 8. Comparison of deltamethrin resistance levels when tested with different insecticidal concentrations using WHO tarsal contact method.

Strain	Dose (mg/cm^2)	LT_{50} (95% FL)	Slope $\pm$ SE	RR_{50}
ICI	20	5.0 (4.7 – 5.2)	13.6 $\pm$ 1.4	-
	0.06	13.5 (12.6 – 14.2)	5.3 $\pm$ 0.4	-
LHFA	20	9.2 (8.0 – 10.1)	3.0 $\pm$ 0.3	1.8
	0.06	1074 (405 – 12970)	0.6 $\pm$ 0.2	80.0
ML11	20	9.5 (8.8 – 10.2)	3.8 $\pm$ 0.3	1.9
	0.06	76.2 (28.9 – 151.3)	0.6 $\pm$ 0.1	5.7

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