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Monitoring for insecticide resistance in field-collected populations of *Blattella germanica* (Blattaria: Blattellidae)

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ABSTRACT

Seven field-collected populations of German cockroach, *Blattella germanica* (L.) (ICN, DNH, CHN, DGU, BSN, GSN, and GWJ), were tested for susceptibility to eight different insecticides by a topical application method, and were compared to an insecticide-susceptible KSS strain. Marked regional variations of insecticide susceptibility were observed. Extremely high to high levels of resistance were observed in bifenthrin [resistance ratio (RR), 46–159], deltamethrin (RR, 61–160), and esfenvalerate [RR, 70–270; except for BSN females (RR, 20) and GSN females (RR, 24)]. Low to moderate levels of resistance were observed in cypermethrin [RR, 16–29; except for DGU females (RR, 88) and BSN females (RR, 41)], permethrin [RR, 11–39; except for DNH females (RR, 110) and BSN females (RR, 44)], chlorpyrifos [RR, 2–13; except for GSN and GWJ females (RR, ca. 140)], chlorpyrifos-methyl (RR, 2–8), and fenthion (RR, 8–17). All of the colonies were susceptible to one or more of the insecticides examined. These results indicate that careful selection and rotational use of these insecticides should result in continued satisfactory control against field populations of German cockroach.

Introduction

The German cockroach, *Blattella germanica* (L.), is one of the most serious household insect pests because of their cosmopolitan occurrence and abundance in homes and other buildings and because it causes allergic reactions and serious respiratory conditions (Weber, 1984; Wirtz, 1984; Schal and Hamilton, 1990; Roberts, 1996; Arlian, 2002). This insect species is also a carrier of intestinal diseases, such as diarrhea, dysentery, and cholera, and a potential carrier of fecal pathogens (Weber, 1984; Wirtz, 1984; Schal and Hamilton, 1990; Arlian, 2002). Various contact and residual insecticides, such as organophosphorus, carbamate, and pyrethroid insecticides, and stomach insecticides such as hydramethylnon, are used to control cockroach populations in Korea. Repeated use of these insecticides has often resulted in the development of resistance (Bang et al., 1993; Shim et al., 1997; Chang et al., 2009). Increasing levels of resistance to the most commonly used insecticides have resulted in multiple treatments and excessive doses, raising serious human health and environmental concerns. Many of the insecticides currently used in Korea have failed to control cockroaches in the field, probably because of the development of resistance. Widespread insecticide resistance has been a major obstacle in a cost-effective integrated cockroach management program in Korea. In addition, factors such as increased costs of labor and pesticide application and safety issues have made cockroach control difficult. Therefore, there is a need to establish an efficient resistance management strategy using available information on the extent and nature of resistance.

Resistance monitoring can be an effective component of the resistance management approach by providing valuable information on the responses of cockroach populations to insecticides. Detection of changes in field resistance can indicate the need for alternative control measures, including use of synergists, rotational use of various insecticides, and reduced insecticide application (Scott et al., 1990; Capel, 1991). Very little work has been done on resistance patterns to the insecticides currently used in cockroach field populations in Korea. Here, we report on the resistance patterns of seven field-collected populations of German cockroaches to eight currently available insecticides.

Materials and methods

Cockroaches

A Korean susceptible strain of German cockroaches (KSS) was maintained in the laboratory without exposure to any known insecticides (Chang and Ahn, 2001). Seven different colonies of German cockroaches were collected from restaurants in Incheon (designated ICN colony), Donghae (Gangwon Province; designated DNH colony), Cheonan (Chungnam Province; designated CHN colony), Daegu

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Table 1
Toxicity of eight insecticides to adult females of the susceptible KSS strain of German cockroaches using topical application during a 24-h exposure.

Insecticide	n[a]	Slope ± SE	LD_{50} (95% CL[b]) μg/female	χ^2
Bifenthrin	300	1.5 ± 0.17	0.0151 (0.0111–0.0196)	2.76
Chlorpyrifos	250	2.2 ± 0.27	0.0062 (0.0049–0.0076)	5.82
Chlorpyrifos-methyl	300	1.6 ± 0.19	0.0070 (0.0052–0.0089)	5.70
Cypermethrin	250	1.2 ± 0.15	0.0200 (0.0137–0.0280)	3.46
Deltamethrin	250	2.0 ± 0.24	0.0054 (0.0042–0.0067)	3.82
Esfenvalerate	350	1.5 ± 0.15	0.0117 (0.0090–0.0149)	8.24
Fenthion	300	1.8 ± 0.15	0.1400 (0.0898–0.1944)	2.77
Permethrin	150	1.0 ± 0.17	0.0289 (0.0170–0.0474)	1.72

[a] Number of cockroaches.
[b] CL denotes confidence limit.

(designated DGU colony), Busan (designated BSN colony), Gunsan (Jeonbuk Province; designated GSN colony), and Gwangju (designated GWJ colony), using sticky traps (Dongho Pharmaceutical, Seoul, Korea) or pit-fall traps (#2838, Bioquip, Rancho Dominguez, CA, USA) from April to September, 2007. The cockroaches were immediately transferred to polyethylene containers (10 × 8.4 cm) with a 200-mesh wire screen attached over a 2.5-cm central hole on the lid. They were reared for three generations to ensure sufficient numbers for testing. Cockroach colonies were reared separately in glass jars (43 cm diameter × 30 cm) containing Purina calf food pellets (Pyeongtaek, Gyeonggi Province, Korea), distilled water and a cardboard shelter. They were held at 27 ± 2 °C and 60 ± 10% RH under a 12:12 h light:dark cycle. Petroleum jelly (SK Chemical, Seoul) was lightly applied to the upper inside surface of the jars to prevent escape.

Chemicals

The eight insecticides examined in this study were bifenthrin (98% purity), chlorpyrifos (99.2% purity), cypermethrin (96% purity), and deltamethrin (98.9% purity) purchased from Sigma-Aldrich (St. Louis, MO, USA) and esfenvalerate (98% purity), permethrin (97% purity), chlorpyrifos-methyl (98% purity), and fenthion (90% purity) purchased from Fluka (Buchs, Switzerland). All other chemicals were reagent grade and available commercially.

Bioassay

Four to 10 dosages of the test insecticides in 0.5 μl of acetone were applied topically to the abdominal sternites of CO_2-anesthetized adult females (5–7 days old). Control cockroaches received 0.5 μl of acetone. They were placed separately onto the bottom section of 300 ml paper cups and provided with food and water.

Treated and control (acetone only) females were held at the same conditions used for colony maintenance. Mortalities were determined 24 h post-treatment. Females were considered to be dead if their bodies or appendages did not move when they were prodded with fine wooden dowels. Each bioassay was replicated three times using 10 females per replicate.

Table 2
Toxicity of eight insecticides to adult females of the ICN colony of German cockroaches using topical application during a 24-h exposure.

Insecticide	n[a]	Slope ± SE	LD_{50} (95% CL[b]) μg/female	χ^2	RR[c]
Bifenthrin	150	1.3 ± 0.26	2.2393 (1.4703–3.3867)	1.55	148.3
Chlorpyrifos	180	1.0 ± 0.14	0.0291 (0.0151–0.0497)	3.43	4.7
Chlorpyrifos-methyl	180	1.0 ± 0.13	0.0499 (0.0259–0.0904)	2.11	7.1
Cypermethrin	150	1.1 ± 0.23	0.5354 (0.3283–0.8751)	0.80	26.8
Deltamethrin	150	1.1 ± 0.17	0.6638 (0.3742–1.0752)	1.89	122.9
Esfenvalerate	150	1.5 ± 0.24	1.7584 (1.2354–2.6384)	2.77	150.3
Fenthion	150	1.7 ± 0.28	2.3419 (1.7014–3.2074)	1.74	16.7
Permethrin	150	1.6 ± 0.27	0.8298 (0.6020–1.2199)	0.59	28.7

[a] Number of cockroaches.
[b] CL denotes confidence limit.
[c] Resistance ratio.

Table 3
Toxicity of eight insecticides to adult females of the DNH colony of German cockroaches using topical application during a 24-h exposure.

Insecticide	n[a]	Slope ± SE	LD_{50} (95% CL[b]) μg/female	χ^2	RR[c]
Bifenthrin	150	2.0 ± 0.28	0.9281 (0.6949–1.2212)	1.35	61.5
Chlorpyrifos	150	0.9 ± 0.17	0.0143 (0.0063–0.0257)	0.56	2.3
Chlorpyrifos-methyl	150	1.1 ± 0.17	0.0283 (0.0165–0.0467)	2.04	4.0
Cypermethrin	150	1.2 ± 0.24	0.3277 (0.1897–0.4953)	2.49	16.4
Deltamethrin	150	1.4 ± 0.25	0.7293 (0.5081–1.1095)	0.15	135.1
Esfenvalerate	150	1.6 ± 0.26	0.8201 (0.5927–1.2159)	1.00	70.1
Fenthion	150	1.7 ± 0.27	1.6583 (1.2241–2.3557)	1.96	11.8
Permethrin	180	1.7 ± 0.25	3.1724 (2.3806–4.2229)	7.10	109.8

[a] Number of cockroaches.
[b] CL denotes confidence limit.
[c] Resistance ratio.

Data analysis

The LD_{50} values and slopes were calculated by probit analysis (SAS Institute, 2004). A resistance ratio (RR) was calculated according to the formula, RR = (LD_{50} value of female cockroaches from the field-collected colony/LD_{50} value of female cockroaches from the susceptible strain). RR values of <10, 10–40, 40–160 and >160 were classified as low, moderate, high, and extremely high resistance, respectively (Kim et al., 1999). The LD_{50} values for each colony and their treatments were considered to be significantly different from one another when 95% confidence limits of the LD_{50} values failed to overlap.

Results and discussion

The susceptibility of KSS female German cockroaches to the eight insecticides examined was evaluated by comparing the LD_{50} values estimated from topical application (Table 1). Based on 24-h LD_{50} values, deltamethrin, chlorpyrifos, and chlorpyrifos-methyl were the most toxic insecticides, followed by esfenvalerate and bifenthrin, then cypermethrin and permethrin. The insecticidal activity of fenthion was the least of any of the insecticides. There was no mortality in the acetone-treated controls.

The toxicity of the eight insecticides to adult females from the ICN colony was compared with toxicity to the susceptible KSS adult females (Table 2). As judged by 24-h LD_{50} values, the ICN females were highly resistant to esfenvalerate, bifenthrin, and deltamethrin. The IR-BG females exhibited moderate and low levels of resistance to permethrin, cypermethrin, and fenthion and to chlorpyrifos-methyl and chlorpyrifos, respectively.

Table 4
Toxicity of eight insecticides to adult females of the CHN colony of German cockroaches using topical application during a 24-h exposure.

Insecticide	n[a]	Slope ± SE	LD_{50} (95% CL[b]) μg/female	χ^2	RR[c]
Bifenthrin	150	1.8 ± 0.28	0.7499 (0.5288–1.0099)	2.86	49.7
Chlorpyrifos	150	1.0 ± 0.17	0.0829 (0.0460–0.1390)	1.79	13.4
Chlorpyrifos-methyl	120	1.0 ± 0.21	0.0520 (0.0241–0.0976)	1.02	7.4
Cypermethrin	150	1.4 ± 0.25	0.3174 (0.1990–0.4573)	0.39	15.9
Deltamethrin	150	1.6 ± 0.26	0.8050 (0.5799–1.1920)	0.53	149.1
Esfenvalerate	150	2.0 ± 0.29	0.8555 (0.6487–1.1874)	2.05	73.1
Fenthion	150	1.7 ± 0.25	1.1338 (0.8088–1.5717)	1.20	8.1
Permethrin	150	1.7 ± 0.26	1.1257 (0.8143–1.5562)	4.89	39.0

[a] Number of cockroaches.
[b] CL denotes confidence limit.
[c] Resistance ratio.