INSECTICIDE SUSCEPTIBITY of FIELD POPULATIONS of GERMAN COCKROACH STRAINS COLLECTED in HOTELS in MEXICO

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Abstract The high level of resistance to organophosphate and pyrethroid insecticides by German cockroaches is due to multiple factors, including the scheduled use of them, and isolated populations. Resistance in field populations have been observed in some Mexican strains, in which control failure with cypermethrin formulations have been reported. However, in Mexico we lack studies regarding insecticide toxicity in the German cockroach. For assessing insecticide toxicity, LD_{50} was determined to four insecticide formulations by topical application. Distilled water and acetone (50/50) were used as solvents. Four resistant German cockroach strains were collected in Ixtapa-Zihuatanejo, Gro. (two strains), Huatulco, Oax., and Mexico City. The Orlando susceptible strain was used as reference. All the strains showed high levels of resistance to the insecticides evaluated. LD_{50} were considerable high, compared with other studies where pure active ingredients are used. Apparently, the solvents present in the formulation increased the insecticide toxicity. The most resistant strain showed a resistant ratio of 2100 for deltamethrin (Mexico City), 178.7 for clorpyrifos (Ixtapa II) , 46.4 for cypermethrin (Huatulco), and 12.2 for bendiocarb (Mexico City). Even when we may expect different LD_{50}'s compared with experiments where the active ingredient is pure, adequately correlated, the results with formulated insecticides could help to make decisions regarding the replacement of insecticides in practical situations.

Key Words Cockroaches, insecticide formulations, bioassay, resistance

INTRODUCTION

The German cockroach, *Blattella germanica* (L.), is considered the most important insect pest in urban areas. Their presence is disagreeable and causes psychological and social stress when they appear in embarrassing situations. They are associated with filthy conditions and are mechanical transmitters of a wide variety of pathogenic bacteria and viruses (Reierson et al., 1988). In recent years, cockroaches have been linked to problems of allergies in humans (O'Connor and Gold, 1999), adding to the reasons for controlling this insect.

In Mexico, the programmed and indiscriminate application of insecticides by pest control operators (PCO's) is the most common control practice, which results in the insect's resistance to the insecticides used. The concept of resistance is not clear for PCO's, and it is common that a single active ingredient is used for more than a year in the same place. In time, this causes the loss of effective active ingredients that can be used against cockroaches. In addition, it is very common that an appropriate application program is non-existent. This is closely related to a lack of adequate inspection and erroneous determinations of pest densities. Commonly, applications are performed on surfaces where the pest is seen, but without inspections to find its refuges, which are left untreated.

Today, resistance management should be of interest, not only to researchers or insecticide companies, but also to the industry of pest control. The potential importance of insecticide management to delay resistance of German cockroaches demands that the areas in which resistance is exhibited be known in order to offer management strategies on a local level. Reierson et al. (1988) report that the German cockroach in Mexico is resistant to insecticides. Unfortunately, they do not indicate which insecticides, the levels of resistance, or the origin of the cockroach populations. This study was conducted to determine susceptibility to insecticide formulations in field populations of the German cockroach, *Blattella germanica* (L.), in Mexican hotels.

MATERIALS and METHODS

Cockroach Collection and Rearing

Cockroaches were collected in restaurants of different hotels: two strains were obtained from hotels located in Ixtapa Zihuatanejo, Guerrero (Ixtapa I and Ixtapa II strains). One strain was obtained in a hotel located in Huatulco, Oaxaca (Huatulco strain); and one more strain was obtained in a hotel located in Mexico City (ADF strain). Each strain was reared in laboratory, and was initiated with at least 100 adults collected with a vacuum cleaner. The susceptible strain (Orlando normal) (ON) was provided by the Urban Entomology Laboratory of the Department of Entomology and Nematology of the University of Florida. This strain has been in continuous culture since 1947 (Koehler and Patterson, 1986). The experiment was conducted at the University of Chapingo, under laboratory conditions of 25±2 °C, RH of 60±10%, and a photoperiod of 12:12 (light:dark). All strains were given ground rat feed soaked in powdered milk and water. To keep the feed fresh it was replaced every other day. To obtain insects of a homogeneous age, first instar nymphs were collected weekly in plastic boxes 15 cm wide, 30 cm long, and 25 cm high.

Insecticides and Bioassays

Four commercial insecticides widely used in Mexico for cockroach control were evaluated. The products were Urban 20 (cypermethrin, emulsifiable concentrate, 21.33% active ingredient, by Agricultura Nacional), Biothrine flow (flowable deltamethrin, 2.5%, by Agrevo), Ficam W (bendiocarb, wettable powder, 76%, by Agrevo), and Dursban 20 (chlorpyrifos, emulsifiable concentrate, by Dow Elanco).

Fifth instar nymphs were anesthetized with CO_2 and topically treated with insecticide dissolved in 1 µl of distilled water/acetone (50:50). The insecticide solution was applied to the first abdominal sternite in 5-10 solutions causing >0% and <100% mortality (Valles and Yu, 1996). Three replications containing 10 cockroaches per concentration were done. Mortality was recorded 24 h after treatment. The insect was considered dead when it was jabbed with a needle and did not move.

Data Analysis

Dose-mortality data were analyzed with the Raymond (1985) probit software. The proportion of resistance (RR_{50}) was calculated by dividing the LD_{50} of each of the field populations by the LD_{50} of the susceptible strain (ON).

RESULTS and DISCUSSION

All strains tested exhibited resistance to deltamethrin, chlorpyrifos, cypermethrin, and bendiocarb (Table 1). However, the highest values were observed for deltamethrin. With this insecticide all strains had an RR_{50} above 182.8. The ADF strain was the most resistant with an RR_{50} of 2100. Scott et al. (1986) documented resistance to this insecticide with an RR_{50} of 21. The populations were highly resistant to chlorpyrifos. The most resistant strain was Ixtapa II with an RR_{50} value of 178.7. The least resistant strain was Huatulco, with a value of 71.2. Similar cases of resistance have been reported by Ballard et al. (1984) and Scharf et al. (1996). With cypermethrin high resistance was also observed. The strain with the lowest RR_{50} was ADF (28.7). The highest RR_{50} value was found for the Huatulco strain (46.3). In the case of bendiocarb,

Table 1. LD_{50} of 5th instar nymphs of different German cockroach strains to four insecticides by topical application

Insecticide	Strain	N	b ± SE	LD_{50} [a]	LD_{95} [b]	x^2	RR [c]
Cypermethrin	Ixtapa I	440	1.98 ± 0.94	3471.4	23,490.1	57.3	28.9
	Ixtapa II	440	2.35 ± 0.19	5054.9	25,338.1	9.5	42.1
	Huatulco	440	3.69 ± 0.38	5557	15,485.3	10.6	46.3
	ADF	440	2.69 ± 0.13	3444.9	14,050.9	18.9	28.7
	ON	400	3.43 ± 0.98	119.8	360.7	5.7	1.0
Deltamethrin	Ixtapa I	330	2.01 ± 0.21	1345.4	8828.4	11.8	182.8
	Ixtapa II	240	4.27 ± 0.49	12,402.9	30,110	7.3	1722.6
	Huatulco	560	2.31 ± 0.38	6923.7	35,627.6	39.1	961.6
	ADF	150	3.58 ± 1.05	15,120.3	43,536.6	7.3	2100.0
	ON	220	2.49 ± 0.31	7.2	32.8	4.2	1.0
Bendiocarb	Ixtapa I	400	2.68 ± 0.56	11,403.9	46,703.5	20.0	12.4
	Ixtapa II	480	2.54 ± 0.22	6476.3	28,725.1	16.8	7.0
	Huatulco	330	2.19 ± 0.23	1898.3	10,630.7	5.3	2.0
	ADF	330	2.29 ± 0.31	16,723.8	97,164.6	7.2	18.2
	ON	400	1.93 ± 0.17	1365.4	6463.5	2.9	1.0
Chlorpyrifos	Ixtapa I	320	3.63 ± 0.36	1365.9	3869.7	5.5	72.2
	Ixtapa II	320	2.71 ± 0.26	3377.6	13,624.9	3.4	178.7
	Huatulco	440	2.2 ± 0.45	1303.3	7272.2	21.9	71.2
	ADF	320	3.9 ± 0.82	1373.3	3622.6	20.7	72.6
	ON	300	5.78 ± 0.73	18.9	614	1.9	1.0

[a] LD_{50} = Lethal Dosis 50 in ppm. [b] LD_{95} = Lethal Dosis 95 in ppm. [c] RR = Proportion of resistance = LD_{50} resistant population/LD_{50} ON.

there was also resistance. The Huatulco strain exhibited the lowest RR_{50} values (2.07), while the ADF strain had the highest values (18.25). Resistance to this insecticide has been documented by Nelson and Wood (1982).

One of the reasons that resistance develops is the constant use of the same insecticides over long periods of time. Where the ADF strain was collected, information on insecticide application during 1997 in the kitchen and bar areas revealed that of 20 applications, 15 were done with cypermethrin. For eight months the same active ingredient was used without rotation. This greatly favors the development of resistance to pyrethroids. Cochran (1987a) has shown that a susceptible colony can develop resistance to permethrin and fenvalerate in six to seven generations after being continuously selected with these insecticides, while in the field, resistance may appear in two years.

The results obtained in this study show that, indeed, pressure from continuous selection with one product provokes the development of resistance. However, it may also be due to the cockroach's high genetic propensity to adapt to environments contaminated by insecticides and the lack of alternative measures of control. Besides these factors, Cochran (1987a) points to others, such as previous history of resistance and the number of generations in which selection occurs.

Resistance to chlorpyrifos appeared even though it is not frequently used in control programs. There may be cross resistance between chlorpyrifos and pyrethroid insecticides. These results are similar to those reported by Scharf et al. (1997), who obtained an RR_{50} of 82.2 and 5.22 to cypermethrin and chlorpyrifos, respectively. They concluded that cross resistance exists between these two insecticides. In other studies chlorpyrifos was used as an alternative to reduce resistance to pyrethroids. However, its continuous use generates conditions for the population to reduce its level of susceptibility (Zhai and Robinson, 1996).

The lowest level of resistance in three of the colonies was to bendiocarb; thus, it would be advisable to consider it within a program of rotation of insecticides. However, its continuous use over long periods should be avoided since the population may develop resistance. This would affect the use of other insecticides such as diazinon, malathion, and propoxur (Nelson and Wood, 1982). On the other hand, the use of organophosphates can be an alternative when the population is resistant to bendiocarb. Generally, it is not advisable to use pyrethroids in rotation with carbamates because they share oxydases as mechanisms of resistance (Cochran, 1987b). But an organophosphate insecticide such as chlorpyrifos, which has been shown to control effectively, may be used after using bendiocarb (Nelson and Wood, 1982). In the specific case of the Huatulco strain and, based on the high values of resistance that were found with cypermethrin and deltamethrin, bendiocarb and chlorpyrifos can be used in a program of insecticide rotation in a similar manner to that described here.

Even when the use of pure active ingredients is the common recommendation for doing insecticide resistance studies, from the practical standpoint it could be more advisable to use commercial formulations when we try to solve a particular problem. Additionally, it is not always possible to obtain the pure active ingredients. We should also be aware that the LD_{50} is higher under these conditions, maybe due to the solvents and other material present in the formulations.

REFERENCES

Ballard, J.B., Gold, R.E., and Rauscher, J.D. 1984. Effectiveness of six insecticide treatment strategies in the reduction of German cockroach (Orthoptera: Blattellidae) populations in infested apartments. J. Econ. Entomol. 77: 1092-1094.

Cochran, D.G. 1987a. Selection for pirethroid resistance in the German cockroach (Dictyoptera : Blattellidae). J. Econ. Entomol. 80: 1117-1121.

Cochran, D.G. 1987b. Effects of synergist on bendiocarb and pyrethrins resistance in the German cockroach (Dictyoptera : Blattellidae). J. Econ. Entomol. 86: 728-732.

Koehler, P.G., and Patterson, R.S. 1986. A comparison of insecticide susceptibility in seven nonresistant strains of the German cockroach, *Blattella germanica* (Dictyoptera : Blattellidae). J. Med. Entomol. 23: 298-299.

Nelson, J.O., and Wood, F.E. 1982. Multiple and cross-resistance in a field-collected strain of the German cockroach (Orthoptera : Blattellidae). J. Econ. Entomol. 75: 1052-1054.

O'Connor, G.T. and Gold, D.R. 1999. Cockroach allergy and asthma in a 30-year old man. Environ. Health Perspect. 107: 243-247.

Raymond, M. 1985. Présentation d'un programme d'analyse log-probit poor microordinnateur. Cah. ORSTOM. Ser. Ent. Med. Et parasitol. 22: 117-121.

Reierson, D.A., Rust, M.K., Slater, A.J., and Slater, T.A.M. 1988. Insecticide resistance affects cockroach control. California Agriculture 42: 18-22.

Valles, S.M., and Yu, S.J.. 1996. Detection and biochemical characterization of insecticide resistance in the German cockroach (Orthoptera: Blattellidae). J. Econ. Entomol. 89: 332-336.

Scharf M.E., Hemingway, J., Reid, B.I., Small, G.J., and Bennett, G.W. 1996. Toxicological and biochemical characterization of insecticide resistance in a field collected strain of *Blattella germanica* (Dictyoptera: Blattellidae). J. Econ. Entomol. 89: 322-331.

Scharf M.E., Kaakeh, W., and Bennett, G.W. 1997. Changes in a insecticide-resistance field application on resistance to pyrethroid insecticides in *Blattella germanica* (Orthoptera: Blattellidae). J. Econ. Entomol. 90: 38-48.

Scott, J.G., Ramaswamy, S.B., Matsumura, F., and Tanaka, K. 1986. Effect of method of application on resistance to pyrethroid insecticides in *Blattella germanica* (Orthoptera : Blattellidae). J. Econ. Entomol. 79: 571-575.

Zhai, J., and Robinson, W.H. 1996. Instability of cypermethrin resistance in a field population of the German cockroach (Orthoptera : Blattellidae). J. Econ. Entomol. 89: 332-336.