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American cockroach control in sewers of Cordoba (Spain)

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ABSTRACT

The control of *Periplaneta americana* in urban areas is a key factor in human health, since cockroaches are transmitters of bacteria, protozoa, helminths, fungi and viruses. The present study analyses the effectiveness of different insecticides on controlling cockroach populations. A series of treatments applied to the sewer system in the city of Cordoba (Spain) was evaluated. The treatments included the use of different compositions such as chlorpyrifos, diazinon, pyriproxyfen and triflumuron. Based on the results, it was observed that chemical products such as chlorpyrifos (Empire 20®) or diazinon (Diacap®) produced better results in the control of *P. americana* than IGRs such as pyriproxyfen (Sumilarv 10 EC®) or triflumuron (Starycide®). The two most efficient products (chlorpyrifos and diazinon) were tested again and chlorpyrifos was shown once more to generate better results. Finally, two different formulae of these products were analysed for efficiency (Empire 20® and M.K.I. 20 LE®) and no statistical difference were observed between them. According to the results, the most efficient product for controlling *P. americana* in the city of Cordoba is chlorpyrifos, regardless of the formula employed, followed by diazinon and finally by the IGRs, which did not produce such good results.

KEYWORDS

P. americana;
IGRs;
Chlorpyrifos;
Diazinon;
Pyriproxyfen;
Triflumuron.

INTRODUCTION

The American cockroach *Periplaneta americana* (L.) is an American native species that has invaded many European countries in the Mediterranean region. In Spain, this species has become one of the most important urban pests that can be found in sewers, steam tunnels and drainage systems of coastal cities.

Along with flies, the American cockroach represents the most important insect vector. This is mainly because it brings together a range of vectors of human pathogens such as bacteria, fungi, helminths, protozoa and viruses[1]. Moreover, a concentration of all these vectors causes allergies in humans due to hypersensivity to certain cuticular proteins and to cockroach excrements or excreted substances[2]. In order to control the cockroach population, it is necessary to take into account their ability to move from the gutters to houses or business establishments. However, Mackie (1969) reported that individual movement in manholes and lateral movements among lateral lines were limited[3, 4].

Successive restrictions in the use of insecticides

against pests posing a health hazard, especially in America and Europe, have necessitated the execution of field studies on the susceptibility of *P.americana* to different families of insecticides, from neurotoxins to the most recently active materials. The simultaneous conduction of these studies in comparable environments may assist the development of control programmes in urban environments.

The effectiveness of different insecticides has been studied specifically for Californian and Singaporean cases[5, 6]. The objective of this study was to analyse the effectiveness of insecticides made from different chemicals and inhibitors in the municipal sewer system of the city of Cordoba (Spain).

MATERIALS AND METHODS

The city of Cordoba is located in southern Spain (37º53'N, 4º47'W) and has a population of about 325,000. The sewer system extends for 790 km, with 29,193 mainlines under paved streets. The main climatological features are very hot summers, with an average above 32.6 ºC, and temperate winters, with an average of 14.7 ºC and minimum temperatures above 4°C. Annual precipitation ranges from 500 to 600 mm.

For this study, 100 manholes were selected. These were located in city districts that had already been inspected to determine the number and abundance levels of cockroaches. Counts were arranged from high to low and sewers were randomly assigned to one of five treatments. One of the treatments involved keeping a control with which to compare the effects of the tested products later. In the other four, the following insecticides with different compositions were used: chlorpyrifos, diazinon, pyriproxyfen and triflumuron (TABLE 1). Sewers were treated once a month for seven months according to the manufacturer's indications and were checked every fifteen days of treatment. In order to determine the efficiency achieved by each treatment, the abundance data gathered for each sample were subjected to evaluation and data analysis. For this, the statistical program Statistical Package for the Social Sciences[7], including the application of the Kruskal-Wallis, Mann-Whitney and Wilcoxon tests, was used[8]. The Kruskal-Wallis test is used to ascertain that a group of data comes from the same population, the Mann-Whitney test is used to check the heterogeneity of two ordinal samples and the Wilcoxon test is used to estimate the median of two related samples and to determine whether there are differences between them.

TABLE 1 : Insecticides

Comercial name	Formulation	Composition	
		Active matter	%
Empire 20®	Microencapsulated	Chlorpyrifos	20
		Proprietary petroleum solvent	10
Diacap®	Microencapsulated	Diazinon	30
		1-benzisotiazol-3-ona	0.2
		Excipients and solvents c.s.p.	100
Sumilarv 10 EC®	Emulsifiable liquid	Pyriproxyfen	10.3
		Excipients and solvents c.s.p.	100
Starycide®	Emulsifiable concentrate	Triflumuron	4.8
		Excipients and solvents c.s.p.	100
M.K.I. 20 LE®	Concentrate	Chlorpyrifos	20
		Excipients and solvents c.s.p.	100
DZN-15®	Concentrate	Diazinon	15
		1,2,4-trimetil benceno	28.2
		Excipients and solvents c.s.p.	100

After the collection of results, a second study was carried out in which the products that had achieved the best results were selected in order to identify significant variations in the use of different formulae. Two formulae were applied for each product; a concentrated and a microencapsulated formula. Each formula was applied monthly for eight months over a two-year duration of the study in ten different manholes; other sewers were also selected for control purposes. In order to determine which formula achieved the best results in controlling *P. americana*, the same statistical tests were applied to the results.

RESULTS AND DISCUSSION

After the first inspection, it was noted that around 97% of the sewers were exclusively infested by *P. americana*. During the first phase of the study, all the

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TABLE 2 : Total number of *P. americana* before and after treatment in sewers.

Toxicant	n	No. Cockroaches													
		Tr.1 (April)	Insp.1	Tr. 2	Insp.2	Tr. 3	Insp.3	Tr. 4	Insp.4	Tr. 5	Insp.5	Tr. 6	Insp.6	Tr. 7 (Oct.)	Insp.7
Chlorpyrifos	20	1220	52	50	45	52	36	34	14	43	30	89	10	0	10
Diazinon	20	760	35	100	105	101	88	95	95	63	12	42	33	32	0
Pyriproxyfen	20	1020	1160	1370	1400	1140	124	138	248	442	403	661	525	334	275
Triflumuron	20	780	751	540	350	228	322	362	571	441	425	519	425	379	214
Control	20	610	623	710	705	645	535	545	830	705	736	895	800	707	680

TABLE 3 : Statistical significance comparing insecticides to the control.

Toxicant	Asymp. Sig. (2-tailed)													
	Tr.1 (April)	Insp.1	Tr. 2	Insp.2	Tr. 3	Insp.3	Tr. 4	Insp.4	Tr. 5	Insp.5	Tr. 6	Insp.6	Tr. 7 (Oct.)	Insp.7
Chlorpyrifos - Control	0.001	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Diazinon – Control	0.189	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Piriproxifren – Control	0.597	0.372	0.045	0.119	0.020	0.003	0.000*	0.000*	0.086	0.019	0.041	0.008	0.008	0.004
Triflumuron – Control	0.614	0.773	0.076	0.007	0.000*	0.000*	0.105	0.233	0.245	0.109	0.048	0.32	0.044	0.001

***, *P* < 0.001; Mann-Whitney Test[7]**

TABLE 4 : Total number of *P. americana* present in new chosen streets before and after treatment in the sewers.

Toxicant	n	No. Cockroaches															
		Feb	Mar	Apr	May	Jun	Jul	Ago	Sep	Feb	Mar	Apr	May	Jun	Jul	Ago	Sep
Chlorpyrifos concentrate	10	7	0	0	0	33	2	0	0	0	6	29	10	53	10	20	25
Chlorpyrifos microencapsulated	10	1310	1620	47	25	14	24	17	5	0	8	15	40	8	10	10	30
Diazinon concentrate	10	295	22	67	2	35	22	41	57	0	17	7	14	61	33	25	50
Diazinon microencapsulated	10	120	35	2	63	23	10	0	0	0	23	15	15	10	18	40	50
Control	10	202	200	315	440	375	310	210	104	255	255	415	290	480	360	370	460

TABLE 5 : Statistical significance comparing insecticides to the control.

Toxicant	Asymp. Sig. (2-tailed)															
	Feb	Mar	Apr	May	Jun	Jul	Ago	Sep	Feb	Mar	Apr	May	Jun	Jul	Ago	Sep
Ch. concentrate-Control	0.001*	0.000*	0.001*	0.000*	0.000*	0.000*	0.001*	0.002	0.001*	0.003	0.000*	0.000*	0.001*	0.001*	0.001*	0.001*
Ch. microencaps.– Control	0.014	0.001*	0.028	0.001*	0.000*	0.001*	0.005	0.007	0.001*	0.005	0.000*	0.001*	0.000*	0.001*	0.000*	0.001*
D. concentrate – Control	0.878	0.005	0.017	0.000*	0.000*	0.001*	0.006	0.203	0.001*	0.011	0.000*	0.000*	0.003	0.008	0.001*	0.001*
D. microencaps. – Control	0.489	0.025	0.001*	0.004	0.000*	0.000*	0.001*	0.002	0.001*	0.018	0.000*	0.000*	0.000*	0.002	0.001*	0.001*

***, *P* = 0.001; Mann-Whitney Test[7]**

treatments used reduced at least a third of the existing population after seven months (TABLE 2). It is important to highlight that, in spite of the treatment, population stocks persisted between July and September because of ensuing climatological circumstances in southern Spain, which present ideal conditions for this species of cockroach with maximum and minimum average temperatures of 36.5 and 18°C. In this case, external temperature seems to be close to the thermal optimum of *P. Americana*[9].

TABLE 6 : Statistical Significance comparing insecticides to different formula.

Toxicant	Asymp. Sig. (2-tailed)															
	Feb	Mar	Apr	May	Jun	Jul	Ago	Sep	Feb	Mar	Apr	May	Jun	Jul	Ago	Sep
Ch. concentrate-Ch. microencaps.	0.829	0.000*	0.005	0.005	0.063	0.016	0.030	0.317	1.000	0.871	0.562	0.261	0.000*	1.000	0.342	0.575
D. concentrate–D. microencaps.	0.299	0.277	0.234	0.001	0.743	0.206	0.013	0.030	1.000	0.661	0.516	1.000	0.019	0.377	0.534	0.936

***, $P < 0.001$; Mann-Whitney Test[7]**

On the other hand, statistical analysis of each treatment product's efficiency carried out by the Mann-Whitney test (considering the significance (P <0.001)) showed that only chlorpyrifos and diazinon caused a significant reduction of the initial population. However, in the case of the IGR pyriproxyfen (a juvenile hormone mimetic), there was only a significant decrease in the fourth month of application. Finally, the IGR triflumuron, which is an chitin synthesis inhibitor, was mainly effective in the third month of treatment (TABLE 3). With the results obtained, it is possible to conclude that chlorpyrifos and diazinon are the products that generated the best results.

Once the most efficient products were determined, the second phase of the study aimed to test different formulae to determine significant differences in efficiency. For this, 50 new streets were chosen to avoid interference with previously applied products. Products were applied during two periods of eight months. The number of cockroaches detected in these streets is listed in TABLE 4.

The same statistical tests were applied to compare the output of each product with the control data (TABLE 5). In this case, the Mann-Whitney and Kruskal-Wallis tests showed that chlorpyrifos produced less significant differences compared to the control data than diazinon, and therefore gave better results. Tests to ascertain which of the chlorpyrifos formulae were more efficient in controlling *P. americana* were subsequently carried out. For this, the Mann Whitney test and the mixed linear model were applied to ascertain whether the time of the year could have had an influence on the results (TABLE 6).

The use of these two tests showed that there was no difference between the two formulae as there were no significant changes, except for two times of the year (March 1 and June 2). The results indicated that the concentrated formula generated better results in March while microencapsulation did so in June. Similar analyses were performed for diazinon and no significant differences could be observed between the two formulae.

To conclude, diazinon (Diacap®) and chlorpyrifos (Empire 20®) yielded better results in controlling *P. americana* populations in the sewers of Cordoba (Spain), while the IGRs (Sumilarv 10 EC® and Starycide®) did not provide such good results. Therefore, it is necessary to find formulae that consistently offer high effectiveness, even for those species with a long biological cycle such as *P. americana*, whose nymph development can last up to fifteen months[10]. On the other hand, the second phase of the study investigating the most efficient products (chlorpyrifos and diazinon) demonstrated that chlorpyrifos offered better results. Finally, tests aimed at determining which formula of the chlorpyrifos was more efficient, concentrated (M.K.I. 20 LE®) or microencapsulated (Empire 20®), did not show significant differences between them.

The results showed that chlorpyrifos persist in the environment for longer, thus offering a longer protection interval against this species. From the perspective of integrated control programmes, it is always essential to alternate active materials to prevent the development of resistance among the target population, especially since the ensuing climatological conditions are favourable to the proliferation of the *P. americana* all year round. Therefore, in the long run and until IGRs are sufficiently effective in reducing populations, the employment of neurotoxins could be of use in the control of *P. americana* populations.

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