ENTOMOLOGY

Drastic reduction in density of *Blattella germanica* and *Periplaneta americana* cockroaches after the application of fenitrothion and lindane in Dema, Zimbabwe

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Abstract

Field studies were conducted in villages near the peri urban Dema area, Seke district, Zimbabwe, in order to understand the effect of the insecticides fenitrothion and lindane on *Periplaneta americana* and *Blattella germanica* cockroaches. A total of 63, 72 and 71 rooms were used for control, fenitrothion and lindane respectively. The mean density per room for *P. americana* before spraying was 43.5, 42.7 and 44.1 for the control, fenitrothion and lindane respectively. The mean density per room for *B. germanica* before spraying was 51.4, 50.2 and 47.1 for the control, fenitrothion and lindane respectively. A reduction in population density of *P. americana* was 3.2%, 83.8% and 99.3% in the control, fenitrothion and lindane rooms respectively. A reduction in population density of *B. germanica* was 87.8% and 82.8% in fenitrothion and lindane rooms respectively. An increase of 9.9% in the control rooms was observed. The majority of *P. americana* cockroaches died one month post spray with fenitrothion killing 78.2% and lindane 37.4% of all cockroach collections. However, the number of dead *B. germanica* cockroaches was almost of the same order for fenitrothion (71.9%) and lindane (74.5%). The residual effect of fenitrothion was 3 months on both cockroach nymph species and that of lindane was 1 month. In conclusion, both fenitrothion and lindane had impact on cockroach density, and fenitrothion showed a residual effect of 3 months.

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Introduction

Various reasons have been associated with the occurrence of cockroaches in households and institutions worldwide, depending on the location. However, the occurrence of cockroaches at household level has not been perceived as beneficial due the observed tendency to contaminate food and furniture with their droppings (Imamura *et al.*, 2003). Infants and children have not been spared from the allergies associated with cockroach excreta (Yang *et al.*, 2017). Several studies were conducted that documented the presence of medically important organisms in cockroaches. Cockroach control requires the use of baits (Durier and Rivault, 2003) and insecticides (Salehi *et al.*, 2016).

Ameen *et al*. (2005) evaluated the efficacy of a 0.05% benzoyl-phenyl urea insect growth regulator (noviflumuron) against *Blattella germanica* cockroaches under laboratory conditions and results showed 100% nymphal mortality 120 days (4 months) after application. Fipronil caused 16-96% mortality of *P. americana* and 51-100% mortality of *B. germanica* cockroaches on different surfaces in a study conducted by Srinivasan *et al*. (2005). The laboratory study by Ameen *et al*. (2005) showed that noviflumuron reduced *B. germanica* population density by 51.9% (when applied at 0.05%), 62.6% (when applied at 0.1%) and 62.6% (when applied at 0.2%) 16 weeks post application (4 months). Field

results of the same study showed a reduction of 73.3% when 0.2% noviflumuron and 90.6% when 0.5% noviflumuron were used (Ameen *et al.*, 2005).

We carried out this study in order to understand how insecticides formulated with fenitrothion and gamma-hexa-chloro-cyclo-hexane (lindane) influence cockroach densities in real field settings.

Materials and Methods

Study area

Research was carried out in villages around Dema growth point, Seke district, Zimbabwe. The study area consists of brick houses that are roofed with asbestos sheeting as well as those made from bricks, mud plastered and containing thatched roofs. Most of the houses are close to each other and crop fields are located at a distance from residential houses. People are involved in subsistence farming and also maintain gardens.

Insecticide formulation

A 48.8% wettable powder formulation containing fenitrothion (organophosphate) constituted one insecticide and this insecticide is registered for use in Zimbabwe. Another wettable powder formulation containing 12% gamma-hexa-chloro–cyclo-hexane (lindane) (organochlorine) was also used and this is also registered in Zimbabwe. Fenitrothion was prepared by mixing 100 mL of insecticide with 9.9L of water in a Hudson Xpert sprayer, mixing well before spraying inside walls and roofs of rooms. Lindane was prepared by mixing 375 g of insecticide with 9.625 L of water, shaking well before application.

Field studies

This study was designed in such a way that it was split into 2 parts; i) the study areas where insecticides were applied and taking account the control area and ii) an area where live cockroach nymphs and adults were being collected for bioassays on a monthly basis.

Determination of population densities

Pre-spraying exercises were conducted in order to determine the population densities of cockroaches (nymphs and adults) by placing attractant traps (350ml bottles containing left over food) in food preparation rooms (kitchens or any other room where food was prepared). The presence of cockroaches was checked on the second day. All cockroaches (nymphs and adults) were morphologically identified and then a yellow tracing dye (powder form), consisting of a dyed/pigmented melamine, sulphonamide, copolymer was applied on them on the second day. These cockroaches were released at the centre of the village and re-trapping was done again. This process was repeated after the application of insecticides (3 months post spray) in order to measure changes in density. The mark–release-recapture population estimation technique by Southwood, (1966) was used. Population estimate of cockroaches was calculated using Southwood's formula (1966) as follows:

$$P = \frac{M * C}{M'}$$

Where:
P = population estimate
M = number of cockroaches marked and released on day 1
C = number of cockroaches caught on day 2
M' = number of marked cockroaches recaptured.

Application of insecticides

The walls and roofs of 63 rooms were sprayed with fenitrothion, 72 rooms with lindane (gamma-hexa–chloro–cyclo-hexane) and 71 rooms were not sprayed with insecticide and served as the control.

Collection of cockroach nymphs for bioassays

Live cockroach nymphs were collected using attractant traps as described in the population estimate method. These cockroach nymphs were kept in mosquito cages and were provided with left-over food until used. These cockroach nymphs were then used for monthly bioassays up to 3 months.

Bioassays

Bioassays were conducted on live cockroach nymphs collected from the second village using attractant traps by using 4 standard World Health Organization (WHO) cones per test measuring 8.5 cm in diameter at the base and 5.5 cm high. The cones were fixed on 4 different positions on the walls of rooms, and then 10 cockroach nymphs were placed inside them and exposed for 30 minutes. The cockroach nymphs were retrieved and kept in 150 mL glass bottles for 24hrs. Bioassays were done monthly.

Data analysis

The data was entered in an EXCEL sheet and analysed using ANOVA (Analysis of variance) method. Significant differences were determined at 95% confidence limit.

Results

Population densities

The application of any of the 2 insecticides resulted in drastic changes in population density per room, irrespective of the species of cockroaches during field studies (Table 1). The population densities of cockroaches were not significantly different at the start of the study for all treatments, including the control (P=0.4). There was a slight decrease in *P. americana* cockroach density in the control and a slight increase in the density of *B. germanica* cockroaches in the control rooms. The percentage reduction in population densities of either *P. americana* or *B. germanica* after the application of either insecticides was of the same magnitude, with no significant difference observed (P=0.6), although significant difference was seen when the controls were considered together with treatments (P=0.001). However, the actual density of *P. americana* after the application of lindane was the lowest and significantly different (P=0.03).

The overall composition of cockroaches before the application of insecticides showed that species diversity constituted 46.7% *P. americana* and 53.3% *B. germanica*. However, after the application of insecticides, *P. americana* constituted 41% (a reduction of 5.7%) and *B. germanica* 59% (an increase of 5.7%). *P. americana* in the control rooms at the start of the study constituted 50.8% of all cockroaches and this decreased to 49.2% after 3 months. The trend for *B. germanica* in the control rooms showed a start of 47.6% and this shifted to 52.4% (4.8% increase) after 3 months later. Treated rooms showed a totally different scenario whereby rooms treated with fenitrothion had 88.1% *P. americana* before application of insecticide and this was reduced to 11.9% (reduction of 76.2%) three months later and this trend was similar with *B. germanica* (89.2% before spraying and 10.8% after spraying) (reduction of 78.4% after spraying). Lindane showed a larger change in

P. americana composition (99.1% before spraying and 0.9% after spraying) (98.2% reduction) and this trend was similar with *B. germanica* cockroaches (85.3% before spraying and 14.7% after spraying) (70.6% reduction).

Effect of insecticides on cockroach mortality in field studies

Over 70% of either *P. americana* or *B. germanica* cockroaches were collected dead from rooms where fenitrothion was applied, 1 month post spray (Table 2). On the other hand, few dead *P. americana* cockroaches were collected from rooms were lindane was applied and the percent mortality was almost of the same magnitude. The effect of lindane on *B. germanica* cockroaches was almost the same with that of fenitrothion for 3 months. A negligible proportion of *P. americana* cockroaches were collected dead from control rooms. The total number of dead *P. americana* cockroaches was 5392, 3571 and 3158 for the control, fenitrothion and lindane rooms respectively. The total number of dead *B. germanica* cockroaches was 6798, 4053 and 3919 for the control, fenitrothion and lindane rooms respectively.

Residual effect of insecticides on cockroach nymphs

All insecticides offered 100% mortality on both cockroach species one month post spray (Table 3). Fenitrothion killed more *P. americana* cockroaches than lindane 2 months post spray and the results were significantly different (P=0.04) and this was the same with *B. germanica* (P=0.043). Complete mortality occurred for both cockroach nymph species when exposed to rooms sprayed with fenitrothion, giving a residual effect of 3 months and this was not realized with lindane. On the other hand, rooms sprayed with lindane showed a residual effect of 1 month on either *P. americana* or *B. germanica* cockroach nymphs.

Discussions and Conclusions

Population densities

Results in this study have shown that the starting baseline was not significantly different in terms of either *P. americana* or *B. germanica* cockroach density, with distinct composition levels of *P. americana* and *B. germanica*. This puts all the 3 treatments at the same level before the study commenced. The impact of insecticides on population densities of both cockroach species showed a marked reduction after application as compared with the control. The highest reduction in cockroach density was recorded in rooms that were sprayed with lindane (on *P. americana*), followed by fenitrothion (on *B. germanica*), fenitrothion (on *P. americana*) and lastly lindane (on *B. germanica*). Under natural behaviour, it

Table 1. Cockroach densities per room before and after application of insecticides during field studies.

	P. americana cockroaches						*B. germanica* cockroaches					
	Control		Fenitrothion		Lindane		Control		Fenitrothion		Lindane	
	N.	Density /room	N.	Density /room	N.	Density /room	N.	Density /room	N.	Density /room	N.	Density /room
Before spraying	2740	43.5[a]	3074	42.7[a]	3131	44.1[a]	3238	51.4[a]	3614	50.2[a]	3344	47.1[a]
3 months after spraying	2652	42.1[a]	497	6.9[b]	27	0.3[c]	3560	56.5	439	6.1[b]	575	8.1[b]
Change	88	1.4	2578	35.8	3111	43.8	321	-5.1	3175	44.1	2769	39.0
% change		3.2%[b] (reduction)		83.8%[a] (reduction)		99.3%[a] (reduction)		-9.9%[b] (increase)		87.8%[a] (reduction)		82.8%[a] (reduction)

Same letter in the same row shows no significant difference. Different letter in the same row shows significant difference.

Table 2. Total number of dead cockroaches during field studies (number of dead cockroaches is shown and percent of all cockroaches over the 3 months period is in brackets).

Month post spray	*P. americana* cockroaches			*B. germanica* cockroaches		
	Control (%)	Fenitrothion (%)	Lindane (%)	Control (%)	Fenitrothion (%)	Lindane (%)
1	0 (0)[a]	4051 (78.2)[b]	12 (37.4)[c]	0 (0)[a]	3863 (71.9)[b]	651 (74.5)[b]
2	0 (0)[a]	1122 (21.6)[b]	10 (31.3)[b]	0 (0)[a]	1211 (22.5)[b]	206 (23.6)[b]
3	1 (0.04)[a]	11 (0.2)[a]	10 (31.3)[b]	0 (0)[a]	302 (5.6)[a]	17 (1.9)[a]
Total	1 (0.02)	5184 (100)	32 (100)	0 (0)	5376 (100)	874 (100)

Same letter in the same row shows no significant difference. Different letter in the same row shows significant difference.

Table 3. Residual effect of fenitrothion and lindane on *P. americana* and *B. germanica* cockroach nymphs (number of dead cockroach nymphs is indicated with percent mortality in brackets).

Month post spray	*P. americana* cockroach nymphs			*B. germanica* cockroach nymphs		
	Control (%)	Fenitrothion (%)	Lindane (%)	Control (%)	Fenitrothion (%)	Lindane (%)
1	0 (0)[a]	40 (100)[b]	40 (100)[b]	0 (0)[a]	40 (100)[b]	40 (100)[b]
2	0 (0)[a]	40 (100)[b]	18 (45)[c]	0 (0)[a]	40 (100)[b]	22 (55)[c]
3	0 (0)[a]	40 (100)[b]	3 (7.5)[c]	0 (0)[a]	40 (100)[b]	5 (12.5)[c]

Same letter in the same row shows no significant difference. Different letter in the same row shows significant difference.

would have been expected that cockroaches emigrated to non-sprayed areas due to the nature of insecticides, this is an unlikely event. Our results on the reduction of cockroach density due to the application of insecticides were higher than those recorded by Ameen *et al*. (2005) on laboratory studies 16 weeks (4 months) post application although field studies showed better results.

Interestingly, our results have shown that insecticides can impact greatly on certain cockroach species than others, showing some selectivity. The reduction in cockroach density by fenitrothion 3 months post spray was experienced at different levels, with more reduction in *B. germanica* than *P. americana* and this was the same with lindane. Our results have shown that the natural species composition in the study area has more *B. germanica* than *P. americana* cockroaches. Such difference in species diversity may indicate that it might not be always possible to extrapolate such results for sites that are totally different, with totally different ecological settings.

Our results have also shown that the level of species diversity may be influenced by control measures instituted, as shown by a reduction of *P. americana* and increase in *B. germanica* after spraying. These results may be linked with the possibility of emigration tendencies of cockroaches that might occur due to various reasons. These results were confirmed in control rooms that showed a similar trend, although this appeared to be species specific. Studies by Durier and Rivault, (2003) and Salehi *et al.* (2016) have shown that the application of baits and insecticides have impact on cockroach infestation and our results agree with these findings. Our results have demonstrated that application of insecticides in rooms may result in meaningful changes in *P. americana* and *B. germanica* cockroach densities.

Residual effect in the field

Our bioassay results have shown that application of fenitrothion had a residual effect of 3 months on both *P. americana* and *B. germanica* cockroach nymphs, implying that this insecticide can be applied once every 3 months. The results on mortality rate of *B. germanica* after application of fenitrothion were not as good as those observed by Ameen *et al*. (2005) on the same cockroach species. On the other hand, lindane had a residual effect of one month on both *P. americana* and *B. germanica* cockroach nymphs. In conclusion, both fenitrothion and lindane had impact on cockroach density, and fenitrothion showed a residual effect of 3 months.

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