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PEST MANAGEMENT

Cost-Effectiveness of Integrated Pest Management Compared with Insecticidal Spraying against the German Cockroach in Apartment Buildings

GH Shahraki[1,2], MN Hafidzi[2], MS Khadri[3], J Rafinejad[4], YB Ibrahim [5]

[1]Fac of Health Science, Yasuj University of Medical Sciences,Yasuj, Iran
[2]Dept of Plant Protection, Fac of Agriculture, Univ Putra Malaysia, Selangor, Malaysia
[3]Institute of Medical Research, Kuala Lumpur, Malaysia
[4]Dept of Medical Entomology, School of Public Health & Institute of Public Health Research, Tehran Univ of Medical Sciences, Tehran, Iran
[5]Fac of Technical and Vocational Education, Sultan Idris Education University, Tanjong Malim, Perak, Malaysia

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Correspondence
Gholam H Shahraki, Fac of Health Science, Yasuj Univ of Medical Sciences, Yasuj, Iran; shahraki.gh@gmail.com

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Abstract

This study assessed the cost and effectiveness of an integrated pest management (IPM) program using hydramethylnon gel baits compared with conventional spraying for controlling the German cockroach, *Blattella germanica* (L.) (Blattodea: Blattellidae), in two residential buildings in Yasuj, Iran. The IPM approach was based on educational programs using pamphlets, posters and lectures, sanitation using vacuuming and application of hydramethylnon gel baits. Conventional approach used cypermethrin (10% EC) on baseboard and cracks-and-crevices. Sticky traps were used as tools for monitoring cockroach population densities. The IPM approach reduced (943%) the rate of insecticide application compared to the conventional spray. Cockroach populations in the IPM treatment were significantly reduced from an average of 12.2 ± 3.01 cockroaches per unit before treatment to zero cockroach per unit by week four and thereafter. Cockroach populations in the conventional spray treatment were reduced from an average of 11.5 ± 4.43 cockroaches per unit before treatment to an average of 3.4 ± 0.99 cockroach per unit after 11 weeks of post treatment. The IPM treatment improved 100% of infested units compared to 78% for spray treatment to obtain a clean level of infestation (< 1cockroach per trap per unit). The results suggest that the intervention by IPM using hydramethylnon gel baits significantly reduced cockroach infestation compared to cypermethrin spray throughout the 11 weeks of post-treatment period. However, within the study period, the IPM system involving gel baits, educational program and sanitation was 363.2% more expensive than the conventional method.

Introduction

Conventional control methods that rely on sprays of residual insecticides have been the primary control method of the German cockroach, *Blattella germanica* (L.) (Blattodea: Blattellidae), in public housing for the past 50 years (Byrne & Carpenter 1986). Extensive use and heavy reliance on insecticides have led to the development of insecticide resistance by the German cockroach (Robinson & Zungoli 1985, Lee *et al* 1999). In

addition to problems of insecticide resistance, the risks associated with the domestic use of insecticides have been of serious concern (Cooper 1999, Greene & Breisch 2002). An alternative approach to the conventional management method is the integrated pest management (IPM). Such approach is based on the integration of multiple control methods including constant scouting, adoption of educational programs, and use of low rate of pesticides (Greene & Breisch 2002, Brenner *et al* 2003). Implementation of IPM (using the least-toxic formulation of insecticides, monitoring system and a briefing) resulted in significant decrease both in quantities of insecticide applied indoors and requests for pest control service by building occupants in Washington, DC, Maryland, and Virginia (Greene & Breisch 2002). Moreover, results of a comparative study of IPM and conventional cockroach control by Nalyanya *et al* (2009) showed that IPM is not only effective at controlling cockroaches but also can lead to long-term reductions in cockroach allergen concentrations, resulting in a healthier environment for residents. Miller & Meek (2004) found IPM was efficient in reducing German cockroach in comparison with the conventional approach. However, the main reason for the persistence of monthly-based insecticide sprays was the inexpensiveness of such method, both in cost and labour (Bennett & Owens 1986). This is a problem for the development of an IPM program against this pest-species. Effectiveness of an integrated pest management intervention in controlling cockroaches using sanitation, monitoring and limited use of low toxic insecticide had been pointed out by Kass *et al* (2009).

Among the recommended gel baits for IPM treatment, hydramethylnon was chosen because : (a) it has not been applied in Iran yet and thus it is less likely to exhibit problems of insecticide resistance; (b) they have low mammalian toxicity (Anon 2002); (c) half-life of hydramethylnon is more than one year (from 375-391) in aerobic soil and stable under high temperature (Anon 2002); (d) gel bait of hydramethylnon is a slow action bait and will thus be most effective 3-14 days (or more) after application (Stejskal *et al* 2004, Wang & Bennett 2006, 2009); (e) the potential for secondary mortality through horizontal transmission of lethal dose due to coprophagy and cannibalistic activities will increase (Silverman *et al* 1991, Lee 2002); (f) the potential for secondary mortality in the absence of cannibalism and necrophagy via residue of hydramethylnon will increase (Buczkowski *et al* 2001); (g) the risk of food contamination by dead cockroaches will decrease (Stejskal *et al* 2004); and (h) since hydramethylnon works slowly, cockroaches will not generally learn to avoid the baits, decreasing the chances of behavioral avoidance (Nalyanya *et al* 2001).

In this study the effectiveness of IPM and conventional control programs of German cockroach was compared based on both efficacy and cost of control.

Material and Methods

The study was carried out in two residential buildings located in Southwestern Iran (Yasuj city). The residential buildings were used as student dormitories of the Yasuj University of Medical Sciences and comprised 125 apartment units. The housing conditions and resident demographics were similar between these two dormitories. Each unit included a single room with a wash basin. Most units have an area of 18 m^2 and a height of 2.5 m. Inspection at all apartments indicated that 92 units were infested with cockroaches. Thirty-nine units were selected for survey. These units which were in different floors and had sizeable German cockroach trap counts (according to cockroach index table) were selected as treatment units. The study units in each floor were randomly divided between treatment groups. Rooms were then classified as IPM units (15 rooms), conventional spray units (12 rooms) and control units (12 rooms). Although sample units for IPM (15 rooms) and conventional (12 rooms) had been used for cost evaluation, only those units with sizeable cockroach trap count and with no missing sticky traps were selected for efficacy evaluation (24 units).

Sticky traps (Ridsect® produced by Sara Lee Malaysia, Petaling Jaya) were used as sampling tools of cockroach populations in the infested sites for a trapping period of 15 weeks. The number of cockroaches was recorded weekly, after which the traps were also replaced. Average number of cockroach trap counts was recorded for four weeks as pre-treatment and for 11 weeks on a weekly basis as post-treatment. Two traps per sampling unit were installed behind refrigerators and under the beds or at other infested areas with one side of the trap resting against a vertical surface.

The units under IPM control were treated with gel-baited releasers, received education, and vacuuming as sanitation. Siege® gel bait (Hydramethylnon 2%; BASF, Malaysia) in a 30 g tube (self applicator) was applied to selected locations. The sites of gel bait application included the cracks and crevices, the sites near the water and food sources (i.e. beside or under stoves, refrigerators and sinks) and other suitable harborages for cockroach (based on darkness, temperature and availability of water and food). Forty to sixty sites were selected for application of droplets depending on the infestation intensity. Hydramethylnon gel was calibrated (according to manufacturer's recommendation) to release the gel at a rate of 0.5 g/m^2. According to this recommendation and to better spread the gel on the surfaces under treatment, 10 droplets of 3 cm long and 0.052 g in weight were applied per m^2. After injection of the gel baits, an educational program was set up by putting up posters, handing out pamphlets, carrying out individual discussions and informative lectures to all students living

in the intervention section under IPM treatment. The importance of sanitation, exclusion and low-toxic control by gel baits for cockroach control had been emphasized in the educational programs. Sanitation as a part of the IPM system using HEPA-filter equipped vacuum cleaners for kitchens (floors and under cabinets) and all rooms, was performed six times in the IPM treatment units.

For conventional control, intervention units were sprayed with cypermethrin (10% EC) after four weeks of pre-treatment. This insecticide, which is currently the most commonly used insecticide in Iran as a conventional control method, was applied at the rate of 5 cm^3/l and with a back-pack sprayer for a comparison with IPM system. Treatment was conducted by spraying baseboard and crack-and-crevices in the treatment sites. The insecticide was applied two times at two weeks apart.

Intensity of infestation (category of infestation) was evaluated based on the cockroach index table (Table 1). Percentage recovery is defined as percentage of improved infested units after the intervention period to obtain clean level of infestation.

The percentage reduction in cockroach trap count was calculated using the Mulla's formula (Mulla 1971): [100-(pre-control/pre-treatment×post-treatment/post-control)×100].

Surveyed items to calculate the cost of IPM and conventional methods are shown in Table 2. Data were analyzed by parametric and non-parametric tests using SPSS software ver.15.0. Data were transformed to obtain a normal distribution and homogeneity of variance. To determine significant differences, Mann-Whitney test or t-test and ANOVA test or Kruskal-Wallis test were employed.

Results and Discussion

Blattella germanica was the most dominant (99.2% trapped cockroaches) and also the targeted species in the surveyed locations. Mean numbers of German cockroaches trapped for 11 weeks after IPM and spray treatments are recorded in Table 3. The results showed

Table 1 Percentage of infested units according to the cockroach index before and after IPM and conventional spray treatments.

Cockroach Index Table (CI)		% CI for treatment units			
Cockroach Index Levels	No cockroach/ trap/ unit (for 7 days trapping)	Pre treatment		Post treatment (wk11)	
		Spray units	IPM units	Spray units	IPM units
Clean	$x < 1$	0	0	78	100
Low	$1 \leq x < 3$	22.2	11.1	0	0
Moderate	$3 \leq x < 8$	33.3	33.3	22	0
High	$8 \leq x < 26$	22.2	44.4	0	0
Very high	$26 \leq x < 50$	22.2	11.1	0	0

Table 2 Average expenses incurred for cockroach control in units treated with IPM and conventional methods

Treatment	n[1]	Labour for treatment	Educational methods[2]	Insecticides applied (for 11 weeks)	Technician time	Sticky trap	Vacuuming
IPM	15	10 h (USD4.2 per unit)	To prepare pamphlets and posters (USD2 per unit)	55.6 gr Siege (USD 1.98 per unit)	To monitor traps and undertake educational lectures (USD1.47 per unit)	To monitor cockroach population (USD2.34 per unit)	6 times sanitation by vacuuming all units (USD 13.2 per unit)
Conventional spray	12	6 h (USD6.8 per unit)	0	79 cc Cypermethrin (USD 0.04 per unit)	0[3](USD 0.97 per unit)	0 (Just to take data were used)[4]	0

[1]Similar units with equal chamber.
[2]Printing cost of pamphlets and posters (Cost for design not included).
[3]This expense was use for trap monitoring but no for a tactic of conventional (was not included).
[4]Although sticky trap was used with similar cost to IPM, trapping was not apply as tactic for conventional.

Table 3 Mean numbers of German cockroaches weakly trapped (no. per sampling unit) during 11 weeks of post treatment.

Treatments	Pre count (mean)^{ns}	Post cockroach trap count										
		Wk1^{ns}	Wk2	Wk3^{ns}	Wk4	Wk5	Wk6^{ns}	Wk7	Wk8	Wk9^{ns}	Wk10	Wk11^{ns}
Spray	11.5±4.43	4.2±3.08	5.2±3.44a	2.2±0.70	1.6±0.78a	0.9±0.61a	5.1±4.11	2.7±1.76a	6.4±1.76a	3.6±3.09	4.4±3.01a	0.9±0.59
IPM	12.2±3.01	6.7±4.11	0.2±0.22b	2.9±2.10	0b	0ab	0	0ab	0b	0	0ab	0
Control	10.0±1.57	13.7±12.14	16.3±11.83a	12.0±8.20	6.3±4.63a	12.7±8.27c	1.3±1.33	3.3±2.17c	11.3±7.04c	1.7±1.67	4.0±1.79c	1.3±1.33

Means within a column followed by the same letter are not significantly different at P = 0.05, Mann-Whitney test; ^{ns}Non significant.

that infestation rate with German cockroach reduced to a clean level after two weeks of IPM treatment and there was a significant reduction (P < 0.05) for IPM treatment versus spray treatments at the 2nd treatment week (Z = -1.738, U = 25, $p_{(1\text{-tailed})}$ = 0.04). Furthermore, infestation rate for the IPM treatment at the 4th treatment week had reduced to zero and remained steady throughout the treatment period, whereas for spray treatment after reduction for five weeks post treatment, variation was seen for subsequent weeks of post treatment. The reduction in cockroach infestation from IPM treatment versus spray treatment was significant (P < 0.05) at weeks four (Z = -1.837, U = 27, $P_{(1\text{-tailed})}$ = 0.03) and eight (Z = -2.191, U = 22.5, P = 0.03) post-treatment. Additionally, IPM intervention showed significant reductions (P < 0.05) as compared to control treatments for weeks two, four, five, seven, eight and 10. Percentage reductions using the Mullas' formula (1971) for the post treatment period (IPM, spray) showed the higher reductions compared to spray treatments for most post IPM treatment weeks, especially after week three of post-treatment.

Survey on mean numbers of all 11 weeks post treatment counts showed significant reduction of cockroach trap counts for IPM treatment compared to spray treatment (P < 0.05; Table 4). Moreover, there was significant reduction (P < 0.05) for IPM treatment versus control treatment in cockroach infestation throughout the post-treatment period. Additionally, percentage reductions throughout 11weeks treatment period were 90.4% and 61.4%, respectively for IPM and conventional spray treatment (Table 4). Therefore, the IPM intervention method showed 29% higher efficacy compared to the conventional spraying method.

Table 4 Mean number of cockroaches trapped with conventional spraying and IPM treatments and control group.

Treatment	n	Pre count (mean)^{ns}	Post count (Mean 11 weeks)[1]	% reduction[2]
Conventional spray	9	11.5 ± 4.43	3.4 ± 0.99a	61.5a
IPM	9	12.2 ± 3.01	0.9 ± 0.41b	90.45b
Control	6	10.0 ± 1.58	7.6 ± 2.61a	-

Means (± SEM) within columns followed by the same letter are not significantly different at P = 0.05; ^{ns}Non significant.
[1]One way ANOVA (F = 8.289, P < 0.05) on log x+1 transformed data.
[2]Corrected by Mullas' formula and Mann-Whitney test (non-normality of data) U = 7, z = -3.599, P < 0.01.

Intensity of cockroach infestation using cockroach index table was calculated for the study units before and after the treatment period (Table 1). The results showed a 78% recovery from infestation (to achieve the clean level) for units on spray treatment compared with 100% recovery for units on IPM treatment after post treatment. Remaining infested units for the spray treatment were in moderate level of infestation.

The results suggest that intervention of IPM method using hydramethylnon gel bait significantly reduced cockroach infestation compared to cypermethrin spray and control group during the 11 weeks treatment period. Results of cockroach trap count for post-treatments (Table 4) substantiated results of percentage recoveries of infested units (100% versus 78% clean level units for IPM and conventional treatments respectively). The results agree with those of Greene & Breisch (2002), indicating that replacing spray insecticide formulations with baits can successfully achieve the major aims of IPM program for public buildings. Miller & Meek (2004) reported long-term efficacy of IPM programs in reducing the average cockroach population in public housing if compared to monthly insecticide sprayings, whereby cockroach populations remained steady for a few months and then increased. Moreover, results of the comparative study of IPM and conventional cockroach control by Nalyanya *et al* (2009) showed that IPM is effective in controlling cockroaches. Also, Wang & Bennett (2006) and Brenner *et al* (2003) showed that IPM can be successful in controlling cockroach in an urban community

Table 2 brings the estimated cost per unit for each surveyed item of IPM and conventional methods. Although monitoring traps had been used for conventional spray units for data collection, this is not a tactic (assumed) for spray treatment in general. In fact, repeated monitoring

Table 5 Amount of pure insecticide (a.i) applied for each method during the two times of the treatment.

Treatment	n	Mean used insecticide (g/unit)		
		1st application[1]	2nd application[2]	Total treatment period[3]
Conventional spray (using cypermethrin)	12	0.323 ± 0.046a	0.332 ± 0.044a	0.66 ± 0.03a
IPM (using hydramethylnon)	15	0.059 ± 0.028b	0.015 ± 0.033b	0.07 ± 0.01b

Means (± SEM) within columns followed by the same letter are not significantly different at P = 0.05, Mann-Whitney test ([1] w = 120, z = -4.449, P < 0.01; [2] w = 120, z = -4.615, P < 0.01; [3] w = 120, z = -4.425, P < 0.01).

is a tactic only for IPM treatment. Thus, cost for this factor (trap and technician time; USD 3.31 per unit) was not included in the cost estimation for the conventional method. A total of 0.07 ± 0.01 g a.i. per unit (3.71 g gel bait) and 0.66 ± 0.03 cc a.i. per unit (6.58 cc cyperpethrin 10%) were used in the surveyed areas during 11 weeks. The amount of cypermethrin (median = 0.630 g/unit) applied was significantly (P < 0.01) higher than hydramethylnon (median = 0.057 g/unit) throughout the study period, assuming that 1 g of a.i. hydramethylnon was equaled to 1 cc of a.i. cypermethrin (density of a.i. for the insecticides is almost equal and the rates are very low) (Table 5). Additionally, the average amount of insecticides for two applications in the treatment units showed that the reduction of applied insecticide for the second stage of the IPM treatment was greater than the first stage compared with the spray treatment. The results indicate that the IPM approach reduced (943%) the rate of insecticide application for cockroach control, as observed by Greene & Breisch (2002), who reported a reduction in both the quantities of insecticide applied indoors and the requests for pest control services by building occupants over the IPM treatment period.

Assuming the cost of USD 16[1] for each 30 g tube of gel bait, the cost for 3.71 g per unit was USD 1.98. The price of one liter of cypermethrin 10% (EC) was USD 5.65, therefore 6.58 cc per unit would cost USD 0.04. Thus, the gel bait cost was almost fifty times higher than the cost of cypermethrin spraying. Comparing the cost of insecticide applied over the period of the study, the IPM system is significantly (P < 0.01) more expensive than the conventional method (w = 79, z = -4.4, P = 0.00). The amount of cumulative gross expenses for the IPM treatment (USD 24.95 ± 0.61 per unit) was significantly (P < 0.01) higher than the two time-spray treatment (USD 6.87 ± 0.03 per unit) throughout the intervention period (Median = 23.8 and 6.8, df = 25, W = 78, z = -4.45, P = 0.00). Therefore the cost for IPM treatment was almost four times higher than the cost of the conventional spray treatment.

Higher applications of typical insecticides such as cypermethrin in the surveyed city lead to a lower price compared to the higher price (international price) for the newly arrived hydramethylnon. The cost of hydramethylnon after introduction and frequent application in this area will eventually reduce its cost to a more competitive level with the commonly applied insecticides such as cypermethrin. However, the bulk of the difference in expenses also comes from the educational program, sticky trap and labour cost in vacuuming for IPM system. Miller & Meek (2004) and Wang & Bennett (2006) reported the cost of the IPM treatment was significantly greater than the traditional treatment initially. However in subsequent treatments, the cost of IPM decreases (Wang 2006).

The IPM system is more expensive than the conventional method at the initial stage, but subsequent application is cheaper because the educational program does not need to be repeated and also the amount of gel bait to be applied is substantially reduced. Additionally after the first gel bait application, residents can learn to apply gel bait injection by themselves further reducing the cost. Comparison of insecticides applied for the second time of treatment of gel bait had shown significant reduction in the application of the latter (Table 5). However the lower price of cypermethrin has misled us into believing that it was cheaper to apply the conventional method of spraying. Williams *et al* (2005) showed that in the long term the cost for IPM and conventional control methods were similar. Therefore, this study demonstrated that, besides being environment friendly, IPM program is an appropriate and preferable alternative to conventional control methods in housing areas, even though the initial application for the IPM system is higher than the conventional control methods.

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[1]Estimated price by manufacturer, May 2009

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