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Original article

Field efficacy of siege gel bait in an IPM program on life stages of German cockroach (Blataria, Blattellidae) in a residential building

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Background: Current control strategies that rely on residual contact insecticides have resulted in insecticide resistance or tolerance to all the major groups of insecticides. New strategies are based on repeated monitoring, sanitation, educational programs and use of pesticides such as gel bait.

Objective: Investigate the effectiveness of an Integrated Pest Management (IPM) program on life stages of German cockroaches at infested units of a residential building in southwestern Iran.

Methods: Life stages (adult, nymph, and ootheca) of German cockroaches at 53 units (rooms) were monitored by sticky traps for eight months. The infested units were subjected randomly to IPM treatments and compared to controls following five weeks of monitoring. The IPM approach was based on an educational program using pamphlets, posters, lectures, sanitation with vacuuming, and application of hydramethylnon gel baits.

Results: There was a high proportion of nymph population (76% of cockroach trap counts) before treatment. German cockroaches showed the highest frequency distribution in trap counts at surveyed residential units. Percentage reduction in nymphs was lower than the reduction in adults in the first week post treatment, although from the fourth to the twenty-sixth week, the percentage reduction was higher than in adults or equal when they reached 100% reduction. Mean total results showed significant reduction in adult and nymph stages throughout the treatment period. Reduction in ootheca fluctuated over the IPM program.

Conclusion: Siege gel bait (Hydramethylnon 2%) in an IPM program successfully reduced adult and nymph stages of German cockroach infestation over the post treatment weeks especially after the fourth post treatment week.

Keyword: German cockroach, hydramethylnon, integrated pest management, siege

There are three important species of domiciliary cockroaches in the world. They are the German cockroach (*Blattella germanica*), the American cockroach (*Periplaneta americana*) and the Oriental cockroach (*Blatta orientalis*). They have a wide distribution. They are commonly found in buildings [1]. The importance of domestic cockroaches as disease carriers and allergies is well established. Until recently, the control of cockroaches relied largely on sprays using synthetic insecticides. Shared plumbing systems and poor sanitation contribute to the severity of cockroach infestations [2]. Thus, partial treatment of a building did not eliminate cockroaches in a majority of the test apartments [3, 4]. The concept of secondary transmission of toxic baits in German cockroach control [5] is a new strategy for control programs. Moreover, gel baits can be selectively applied where the cockroaches are living, such as in areas with food preparation [6]. Gel baits are usually

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applied directly into cracks and crevices by using syringes or bait guns. Furthermore, positive impact of sanitation on gel bait treatment has been shown [7, 8]. Successful nonchemical techniques such as sanitation and vacuuming for cockroach control [9, 10] together with gel bait treatment constitute an IPM control program [3].

Our study was performed to evaluate the effectiveness of the IPM control approach on all life stages (adult, nymph, and ootheca) of German cockroaches using hydramethylnon gel baits in combination with vacuuming and educational programs in a residential building.

Materials and methods

A residential building composed of 53 units located in Yasuj city, southwestern Iran was selected for this study. The residential building is a girl student dormitory of Yasuj University of Medical Sciences. Each unit includes a single room with a washbasin. Most units have an area of 18 square meters and a height of 2.5 meters. Baited tent-form sticky traps (Ridsect®, Petaling Jaya, Malaysia) were used for monitoring cockroach populations in infested units. The trapping process was conducted over a 31-week period. The trap catch data (number of cockroaches, life stages, and species) were recorded weekly after each seven days trapping period. Depending on the surveyed places, traps were installed in cabinets, under sinks, beside refrigerators, and stoves in closets and on shelves.

The infested units that have a sizeable German cockroach infestation were divided randomly for intervention and control groups and were monitored continuously. Intervention units were treated by the injection of gel baits, educational programs and sanitation. Siege® gel bait (hydramethylnon 2%) in a 30g tube (self-applicator) produced by BASF (Shah Alam, Malaysia) was applied to selected locations. Siege® had been calibrated (according to manufacturer's recommendation) to be applied at the rate of 0.5g per square meter. According to this calibration and for widespread effects (fragmentation), 10 droplets (3cm long and 0.052g in weight) per square meter were applied at the infested sites. The sites of gel bait application included cracks and crevices, beside or under the washing machines, stoves, refrigerators, sinks, and cupboards.

After injection of the gel baits, an educational program was initiated by putting up posters, handing out pamphlets, individual discussions, and conducting informative lectures to all students in the intervention section on methods used. The sanitary approach consisted in using HEPA-filter equipped vacuum cleaners for kitchens (floors and under cabinets) and all rooms. It was performed several times (weekly). The percentage reduction (PR) in cockroach trap counts was calculated using the following formula:

$$PR = 100 \quad [(T_0 - T_i) / T_0]$$

T_0 is the mean number of cockroaches trapped pre-treatment

T_i is the number of cockroaches trapped at the i^{th} week post-treatment and for total results, it is the average number of cockroaches trapped per week throughout the i week post-treatment

Intensity of infestation (category of infestation) was evaluated based on cockroach index as shown in **Table 1**. To correct percentage reductions (with effectiveness of control reduction), the formula of Mulla [11] [100-(pre-control/pre-treatment x post treatment/post control) x 100] was used. Percentage reductions and infestation rates for the intervention and controls groups were analyzed by parametric and non parametric tests in relation to the results of exploratory tests (for normality of data using kolmogorov-smirnov test) and Levene's test (for homogeneity of variance) for data by using SPSS software ver.15.0. Wilcoxon and Mann-Whitney test or t-tests to determine significant difference were employed for data analysis.

Table 1. Cockroach index

No. of captured cockroaches per trap	Cockroach index
$0 \leq x < 1$	Clean
$1 \leq x < 3$	Low
$3 \leq x < 8$	Moderate
$8 \leq x < 26$	High
$26 \leq x < 50$	Very high
$x \geq 50$	Abundant

Results and discussion

Ninety four percent of occupants for all surveyed units and 88% of occupants for cockroach-infested units of the residential buildings have not been using insecticides. Therefore, the residual effects from the previous insecticide applications were minimal.

Inspection on sticky traps at the girls' dormitory showed that 71.7% of units were infested with *B. germanica*. Moreover, 15.1 and 1.9% of units were infested with *P. americana* and *B. lateralis* respectively. Results of infestation rates for the three life stages (adult, nymph, and ootheca) of cockroach trap counts after 13 weeks post treatment were recorded in **Table 2.**

Progress of percentage reductions for the three life stages can be seen in **Figure 1**. It shows that percentage reduction for nymphs was lower than for adults in the first week of post treatment, although from the fourth week to seventeenth week the percentage reductions were higher than adults. After that, they remained equal for both nymphs and adults until they reached 100% reduction. The high rates of nymph trap count before treatment (76% of cockroach trap counts) and slow action of applied bait could lead to the low reduction (especially for nymph) in the first week of treatment. Moreover, a high rate of nymph population is a sign of high reproductive rates and monitoring traps were placed close to the cockroach nests (active sites). Nymphs generally move short distances to feed and we can see them around the nests (and thus near to installed trap). Although adults are most resistant to desiccation and move longer distances to feed [12], the nymphs showed higher reductions than adult after the fourth treatment week. Progress of reductions for nymph stages of post trap counts showed significant reductions compared to pre treatment throughout the post treatment weeks (**Table 2**). The progress of reductions for adult stages of post trap counts showed significant reductions ($p<0.05$) compared to pre treatments throughout the post treatment weeks (except for seventh and eighth post intervention weeks; for week 6 $p_{(1\text{-tailed})}<0.05$). Total mean life stages of cockroach trap counts throughout the post intervention weeks showed significant reduction compared to pre-treatment (adult: $t=5.15$, $p=0.00$; nymph: $t=2.61$, $p=0.02$ on $\log_{10}$ (mean+1) transformed data). Due to reduction of feeding and drinking for female during the oviposition period [13], they were least likely to get into contact with the baits and traps during monitoring. Followed low numbers of collected ootheca carried by female, resulted fluctuation for trapped ootheca throughout post treatment weeks (**Figure 1**). However, the total mean of post treatment shows significant reduction for collected oothecas compared to pre treatment ($z=2.29$, $p=0.02$ and 75.9% reduction of mean).

Table 2. Evaluation of differences between pre and post German cockroach trap counts for three life stages (adult, nymph, and ootheca) through the 13 weeks post IPM treatments at the residential building

Cockroach life stages and tests	Mean of pre-treatment (cockroach/ trap)	Mean of post treatment weeks (cockroach/ trap)							
		week 1	week 4	week 6	week 7	week 8	week 10	week 12	week 13
Adult	4.07	0.73	0.30	1.14	1.18	0.95	0.34	0.55	0.16
Tests*		Z=-3.95	Z=-4.01	Z=-1.72	Z=-0.76	Z=-0.97	Z=-3.1	Z=-1.96	Z=-3.45
		P=0.000	P=0.000	P=0.08	P=0.45	P=0.33	P=0.002	p=0.05	P=0.001
Nymph	12.62	8.27	1.51	2.49	1.36	0.64	0.09	0.95	0.48
Tests*		Z=-2.84	Z= 3.38	Z=-2.81	Z=-3.00	Z=-3.75	Z=-3.36	Z=-3.13	Z=-3.17
		P=0.04	P=0.001	P=0.005	P=0.003	P=0.000	P=0.001	P=0.002	P=0.002
Ootheca	0.29	0.27	0	0.14	0	0.42	0.08	0.05	0.05
Tests*		Z=-1.42	Z=-3.06	Z=-1.59	Z=-2.7	Z=-0.62	Z=-2.44	Z=-2.54	Z=-3.11
		P=0.15	P=0.002	P=0.11	P=0.007	P=0.53	P=0.01	P=0.01	P=0.002
Total life stages	16.69	9	1.81	3.62	2.54	1.59	0.43	1.5	0.64
Tests*		Z=-3.38	Z=-3.92	Z=-2.31	Z=-2.57	Z=-2.46	Z=-3.50	Z=-3.07	Z=-3.34
		p=0.001	P=0.000	P=0.02	P=0.01	P=0.01	P=0.000	P=0.002	P=0.001

*Difference between pre and post treatment weeks via Wilcoxon Signed Ranks Test and $p<0.05$

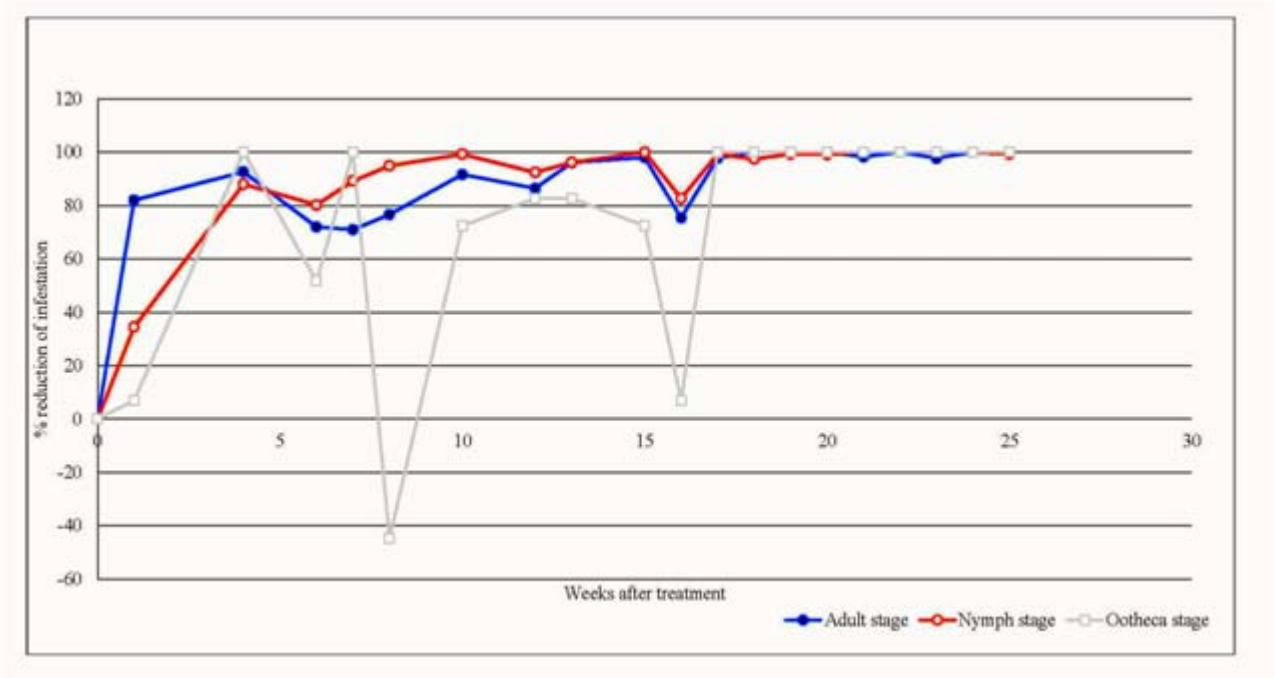

Figure 1. Progress of percentage reduction of trapped German cockroach life stages throughout the 26 weeks IPM treatment at the residential building

Table 3 shows that there were significant reductions ($p<0.05$) for adults and nymphs post intervention counts (mean 26 weeks of post intervention) compared to the control group. Impact of the IPM approach on significant reduction of nymph stages of cockroach trap counts (87%) compared to 0.85% increase for the control group shows that intervention had an impact on the cockroach population in the survey sites. Due to infestation reduction for the two treatment groups, Mulla's formula [11] to correct percentage reduction (with effectiveness of control reduction) was used for the intervention group. Thus, corrected percentage reductions for intervention groups were 88.11, 66.14, and 26.21% for adult, nymph, and ootheca respectively.

Figure 2 shows a progressive reduction of monthly infestation rates of cockroach trap counts throughout the study period after intervention. From June to September (summer season) the differences between infestation rates for the two treatments were remarkable, although there was a gentle slope for the control group. However, throughout the autumn (October, November, and December) infestation rates decreased immediately for the control group and the difference between the two groups is not evident. Mean of infestation rates throughout autumn showed significant reduction of post intervention (0.35 0.15) and control group (1.8 0.51) at $p<0.05$ ($U=12$, $z=-2.406$). Immediate reduction in monthly infestation rates for the control group shows that the cooler weather in autumn had an effect on the infestation

Table 3. Mean percentage reduction of life stages of German cockroach trap counts at the residential building

Treatments (n)	Pre treatment (mean)			Post treatment (mean)			Mean of % reduction		
	Adult	Nymph	Ootheca	Adult[1]	Nymph[2]	Ootheca	Adult[3]	Nymph[4]	Ootheca
Intervention (11)	4.07a	12.62a	0.29a	0.34a	0.95a	0.07a	83.3a	86.6a	57.6a
Control (12)	3.6a	11.57a	0.63a	2.54b	2.57b	0.20a	20.6b	-0.85b	74.1a

Mean within a column followed by the same letter are not significantly different at $p>0.05$, Mann-Whitney test. [1]$U=3$, $z=-3.878$, $p=0.000$, [2]$U=27$, $z=-2.4$, $p=0.016$, [3]$U=9$, $z=-3.383$, d.f=21, $p=0.001$, [4]$U=30$, $z=-2.003$, d.f= 21, $p_{(1\text{-tailed})}=0.027$

rate, although the outside temperature could not affect the infestation rate (due to indoor activity for German cockroaches). It is possible that the design of the dormitory building (separate rooms and common kitchens and bath rooms) made them more susceptible to the effects of outside temperature. A previous study reported that strong population fluctuation is positively correlated with temperature and photoperiod and negatively correlated with barometric pressure. It showed high rates of mortality and moderate rates of population increase for German cockroach populations during the autumn months [14].

A 91% recovery of infestation (to achieve a clean level of infestation) was observed for intervention units at the twenty-sixth post treatment week. The remaining infested unit was at low level of cockroach infestation. Furthermore, percentage recovery for mean of infested units throughout the treatment period was 91% to achieve clean (54.5%) and low (36.4%) level of infestation. Actually low and clean levels of infestation (<3 cockroach per trap per unit) for intervention units over the intervention period are in accordance with scope of IPM program.

Efficacy of the IPM approach to reduce cockroach infestation in New York City public housing after three and six months intervention was reported [15]. Field efficacy of educational programs, the use of least-toxic pest control and performing repairs of residential buildings in two community health centers in East Harlem, New York City [16] showed a 51.6% recovery of infestation after six months intervention. In an IPM program including educational programs, flushing and vacuuming combined with gel bait application and monitoring with sticky traps [3] reported one remaining infested apartment (from 12 survey apartments) with high level of infestation (>12 cockroaches) after 29 weeks intervention.

Conclusion

The IPM approach, using siege gel baits and vacuuming and educational programs successfully reduced German cockroach infestation, especially after a four weeks lag in infestation reduction. Progress of reduction for nymph and adult stages of cockroach infestation was similar throughout the intervention period after a lag in reduction, although higher reduction for nymph before autumn was observable. Reduction of temperature in the fall season affected the cockroach infestation rate, although the German cockroach is usually found inside buildings.

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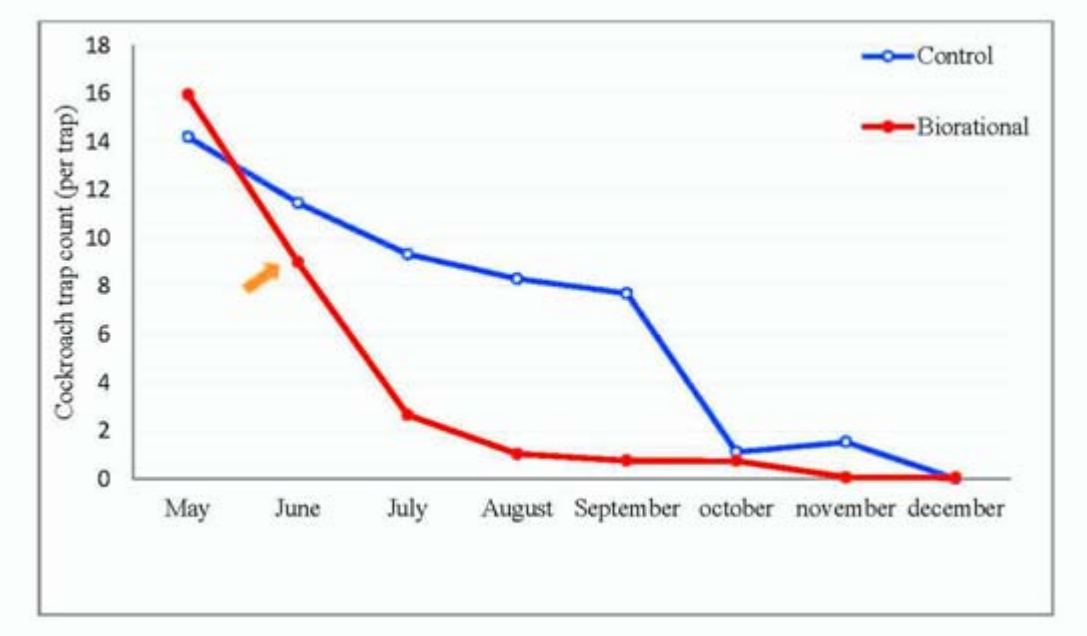

Figure 2. Monthly mean of infestation rate pre and post treatment counts for eight months monitoring at the residential building. Arrow shows start time of intervention.

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