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Biorational control programme for the German cockroach (Blattaria: Blattellidae) in selected urban communities

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Abstract. This study assessed the effectiveness of a biorational control approach using 2% hydramethylnon gel bait on German cockroaches, *Blattella germanica* (L.) in some residential and hospital buildings in South Western Iran. In total, three buildings consisting of 150 apartment units and 101 hospital units were monitored weekly via sticky trap for German cockroach infestations over a period of eight months. These infested units were randomly subjected to intervention and control treatments. Pamphlets and posters were provided and lectures were given to support the educational programmes as a tactic of the biorational system. Survey on cockroach index for intervention units showed 67-94% recovery to achieve clean level of infestation for intervention units of the residential buildings and 83% for the hospital. Mean percentage reductions for treatment groups throughout the 15-week treatment period were 76.8% for the residential buildings and 88.1% for the hospital, showing significant differences compared to the control groups. Linear regression of infestation rates were recorded weekly after treatment and their negative slope for treatment groups substantiated significant reductions for interventions. The results of this study showed that biorational control method, using gel bait, educational programmes and sanitation, is an effective way to manage German cockroach infestation.

INTRODUCTION

The German cockroach, *Blattella germanica* (L.), is the most common indoor species, especially in multiple-family dwellings and probably the most prominent pest cockroach in many parts of the world (Goddard, 2003). Years of difficulty in controlling cockroach infestations have led to the application of large amounts of various insecticides over long periods (Majekodunmi *et al.*, 2002). Studies have confirmed that the use of chemical insecticides is quite common in urban communities (Adgate *et al.*, 2002; Whyatt *et al.*, 2002; Berkowitz *et al.*, 2003). The current control strategy which relies heavily on residual contact insecticides has resulted in the development of insecticide resistance or tolerance to all the major groups of insecticides (organochlorines, organophosphates, carbamates and pyrethroids) in field populations of this species (Cochran, 1995). This has led to the application of even more insecticides in the attempt to increase the number of killed insects; which has eventually induced further resistance and has endangered non-target species (Majekodunmi *et al.*, 2002).

Due to the problems encountered, the concept of biorational approach is recommended as an alternative. Biorational means having minimal disruptive effect on the environment and its inhabitants. In this approach, to reduce frequent application of harmful insecticide and to more accurately target the pest species, and at the same time reducing the potential for inducing resistance, a range of insecticides applied as bait have been developed (Milio *et al.*, 1986; Lucas & Invest, 1993).

Christensen (1991) reported sanitation as an important factor to affect bait performance against German cockroaches in the field. In addition, the effectiveness of educational programmes for building residents to accept and comply with a biorational control programme has been reported by many researchers (Campbell *et al.*, 1999; McConnell *et al.*, 2005; Wang & Bennett, 2006).

With the reduction of available food and water source in the environment, cockroaches will be more likely to get into contact with the baits (Lee & Lee, 2000b) and more vulnerable to insecticides (Lee *et al.*, 1996; Lee & Lee, 2000a). Thus sanitation as a component of the biorational control method can be applied with low-toxic insecticide baits.

Among the recommended gel baits for German cockroach control, hydramethylnon was chosen, because it has low mammalian toxicity and is a slow action bait, being most effective three or more days after application (Stejskal *et al.*, 2004); it also increases the potential for secondary kill (horizontal transmission of lethal dose by coprophagous and cannibalistic activities) (Silverman *et al.*, 1991; Lee, 2002). Hydramethylnon also decreases the risk of food contamination by dead cockroach as it rapidly paralyzes the baited cockroach (Stejskal *et al.*, 2004) and moreover, due to the delayed reaction it causes, cockroaches will not generally learn to avoid it, thus decreasing the probability of behavioural resistance (Nalyanya *et al.*, 2001). The objective of this study is to evaluate field efficacy of the biorational approach using gel baits, such as hydramethylnon, on the German cockroach in three types of study locations with no history of use of such method.

MATERIALS AND METHODS

After survey on 656 sites (including units for 11 dormitories and 2 hospitals, apartments for 7 housing complexes, housings for 100 private houses, 22 rooms for official places and kitchens for 5 restaurants) in South Western Iran, three different types of locations (dormitories, apartment units and hospital units) were selected for study. A total of 101 rooms in the hospital, 25 apartments of the residential building F and 125 units of two dormitories (I and G) were monitored for cockroaches by sticky traps. Dormitories 'G and I' were single dormitories for single girl and boy students respectively in Yasuj University of Medical Sciences (YUMS). They comprised of 47 and 56 residential units, 6 and 16 kitchens and 250 and 220 occupants in 5 and 4 floors respectively. Mostly each unit had an area of 18m^2 and a height of 2.5m. Each unit included a single room with a wash basin and toilet for dormitory I and without them for dormitory G. House building F belonging to YUMS comprised of 25 apartments in five floors and 186 residents. Each unit (60m^2 and 2.5m height) had two small bedrooms, an open kitchen, with a bathroom and toilet. Furthermore, the hospital chosen for survey consists of 10 sections in 3 floors and 101 rooms. Mostly each room had an area of 12-24m^2 and a height of 3m. The rates and levels of infestation before treatment are recorded in Table 2. Survey by questionnaire showed that 44% of the occupants for the study locations had been using insecticides (55.6% by baiting, 22.2% by spraying, 22.2% by dusting and13.9% by spraying and dusting) and 86% of whom had applied insecticides more than one month prior to the survey. Therefore the residual effects from the previous insecticide applications were minimal. The infested units of these sites were randomly subjected to intervention and control treatments.

Baited tent-form sticky traps (Ridsect® produced by Sara Lee Malaysia, Petaling Jaya) were used as tools for monitoring cockroach populations in infested units. Depending on the surveyed places, traps were installed in cabinets, under sinks, beside refrigerators and stoves, in closets, on shelves, and other infested areas, with one side of the trap resting against a vertical surface. The trap catch data (number of cockroaches, life stages and species) were recorded weekly (i.e. after the 7-day trapping periods) over an 8-month period. Old traps that had become dirty or damaged were replaced during constant follow-ups. Totally 1042 sticky traps were used in these four study locations during trapping.

After the initial 3-4 weeks of monitoring, Siege® gel bait (hydramethylnon 2%) in a 30g tube (self applicator) produced by BASF (Shah Alam, Malaysia) was applied at the rate of 0.5g/m^2 (in accordance with the producer's recommendation). According to this calibration and for a more widespread application (fragmentation) each injection (droplet) was 3cm long and 0.052g in weight; thus ten droplets had been applied with an application spread of 0.5g/m^2. This means about 40-60 droplets were applied for single infested units and 100 droplets were applied for kitchens with respect to the intensity of infestation (2-3g/room and 5g/kitchen). The sites of gel bait application were cracks and crevices beside or under washing machines, stoves, refrigerators, sinks, cupboards and other suitable harbourages for cockroach in bathrooms, toilets, sitting rooms and kitchens.

After injection of gel baits, an educational programme was set up by putting up posters, handing out pamphlets, individual discussions and conducting informative lectures to students and other occupants in the intervention section on tactics of the biorational system. A lecture was carried out for resident students (in intervention sites) who were students of science departments and in the *age group* of 18-25 years old. The importance of sanitation, exclusion and low-toxic control by gel bait for cockroach control was emphasized. Occupants of other intervention sites were given guidance about biorational control by face to face interactions. Moreover, putting up posters and handing out pamphlets were done for all occupants in intervention sites. Sanitation – as a part of the biorational system – using HEPA-filter equipped vacuum cleaners (LG VF-4501HTV, Korea) for kitchens (floors and under cabinets) and all rooms, was performed four times in treatment units of surveyed dormitories and house building.

The cockroach index to evaluate the intensity of infestation was determined for surveyed sites (Table 1). Percentage recovery of infested units to achieve a clean level of infestation according to the cockroach index table was calculated for all study locations.

The percentage reduction (PR) in cockroach trap count was calculated using the following formula:

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

where,

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

Percentage reductions and infestation rates were analyzed by parametric and non-parametric tests (Wilcoxon and Mann-Whitney or t-test, Pearson or Spearman's correlation) in accordance with the results of exploratory test (for normality test) and Leven's test (for homogeneity test) using the SPSS15 software. To correct the percentage reductions for those places which had infestation reduction for two groups, Mulla's formula (Mulla, 1971) [100 – (pre-control / pre-treatment × post-treatment / post-control) × 100] was used.

Data were also analyzed by linear regressions of mean number ($\log_{10}$mean+1) of captured cockroaches over time for each treatment to show whether or not the treatment had significant effects on cockroach populations (Appel, 1990; Appel & Benson, 1995; Smith II *et al.*, 1995; Appel & Tanley, 2000; Lee & Yonker, 2003). Thus, the effectiveness of the programme was evaluated in three ways: linear regression, percentage reduction, and percentage recovery.

RESULTS AND DISCUSSION

Among the total of 7,257 cockroaches trapped, *Blattella germanica* species was the most abundant, comprising 96.7%. The other identified species in order of abundance were: the Turkestan cockroach (*Blatta lateralis*) (2.2%), the American cockroach (*Periplaneta americana*) (0.9%), the Brown-banded cockroach (*Supella longipalpa*) (0.07%), and the Oriental cockroach (*Blatta orientalis*) (0.03%). Surveys on study locations showed that a mean of 66% and 67% of the German cockroach-infested sites were observed in the residential buildings and the hospital respectively (Table 2).

Progressive percentage reductions of weekly infestation rates are shown in Figures 1 to 4. They indicated considerable reductions after two weeks for girls' dormitory I ($\geq$80%) and boys' dormitory G (>80%) throughout the programme. Figures 1 to 4 show the progress of high percentage reductions which began with a two-week delay. Slow action of Siege® gel bait and the gradual impact of educational programmes (to improve the attitude of occupants about sanitation and exclusion) and sanitation (by vacuuming) were identified as affecting factors contributing to the lateness of effective infestation reductions.

Survey during the weeks of cockroach trap counts before and after treatment for four study locations showed reductions for treatment weeks and significant reductions for some of the weeks ($p<0.05$). Mean analysis of all survey weeks of infestation

Table 1. Cockroach Index for surveyed hospital and housing

No. of cockroaches trapped per trap per unit (for 7 days trapping)		Cockroach Index
Hospital	Housing	
$x < 1$	$x < 1$	Clean
$1 \leq x < 2$	$1 \leq x < 3$	Low
$2 \leq x < 4$	$3 \leq x < 8$	Moderate
$4 \leq x < 9$	$8 \leq x < 26$	High
$9 \leq x < 20$	$26 \leq x < 50$	Very high
$x \geq 20$	$x \geq 50$	Abundant

Table 2. Summary of intensity of infestations and percentage of recoveries

Study locations	No. of surveyed units	Infested units (pre-treatment)	Levels of infestation for treatment units before treatment (%)					Recovery to achieve clean level	Levels of infestation for remaining infested units	Treatment period (wk)
			Low	Moderate	High	Very high	Abundant			
Girls' dormitory G	53	72%	18	27	37	9	9	91%	Low	26
Boys' dormitory I	72	67%	35	18	29	6	12	59%	Low (29%) Moderate (12%)	29
House building F	25	60%	0	50	33	17	0	86%	Low	16
Hospital C	101	67%	0	67	17	16	0	83%	Moderate	15
Mean for residential buildings	150	66%	Low-Abundant					59-91%	Low-Moderate	16-29

rates (before and after treatment) and percentage reductions compared with control groups are shown in Table 3. Mean infestation rates during similar treatment periods (15 weeks) showed significant differences ($p<0.05$) between treatments and control groups for all residential buildings. Table 3 shows significant reductions for mean infestation rates after biorational treatment ($p<0.05$); during treatment period; moreover mean percentage reductions for all surveyed locations showed significant reductions ($p<0.05$). Due to infestation reduction for the two treatment groups (except for 'house building F'), Mulla's formula (1971) to correct percentage reduction (with effectiveness of control reduction) was used for the three study locations. Thus, corrected percentage reductions for treatment groups were 76.8%, 79.2%, 83.4% and 88.1% for girls' and boys' dormitory (during the 26 and 29 weeks), house building and hospital (during the 16 and 15

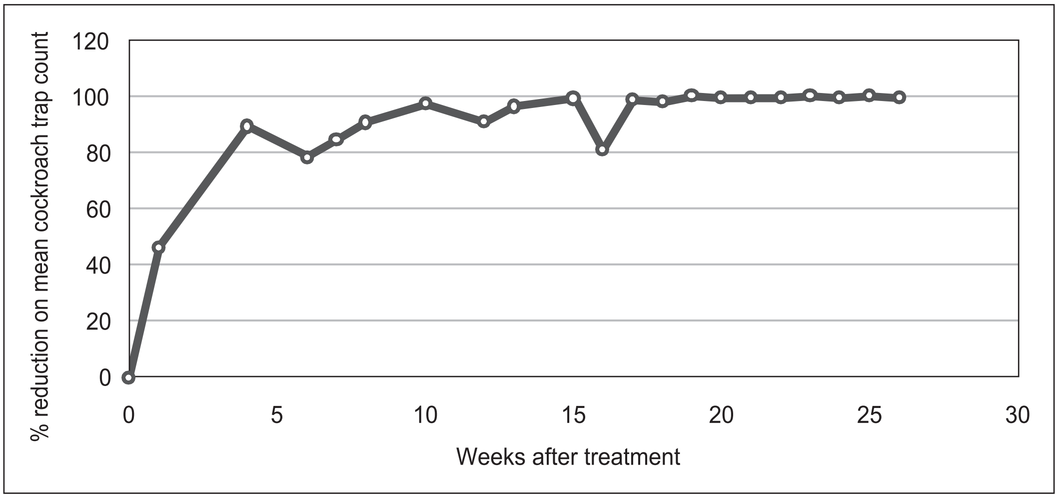

Figure 1. Progress of percentage reductions of mean German cockroach trap counts throughout the 26 weeks of biorational treatment for "girls' dormitory G"

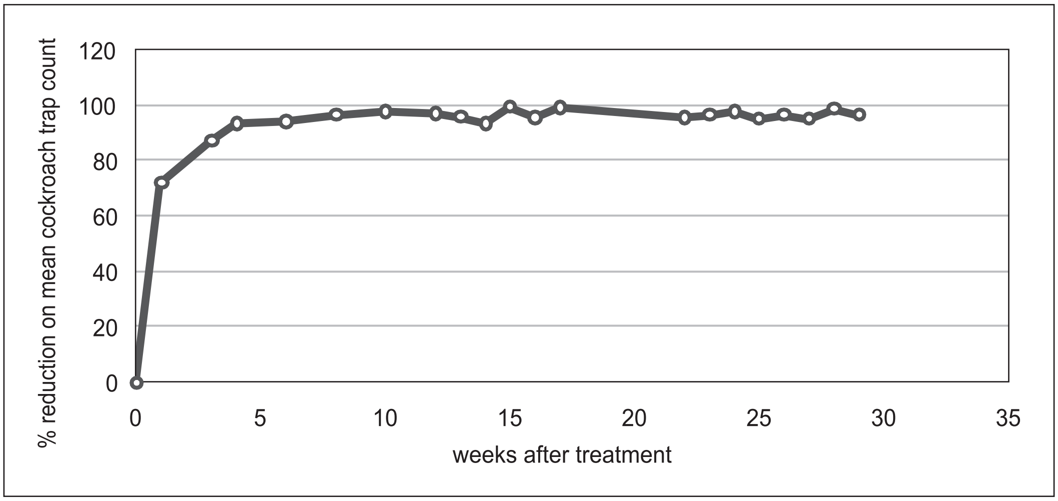

Figure 2. Progress of percentage reductions of mean German cockroach trap counts throughout the 29 weeks of biorational treatment for "boys' dormitory I"

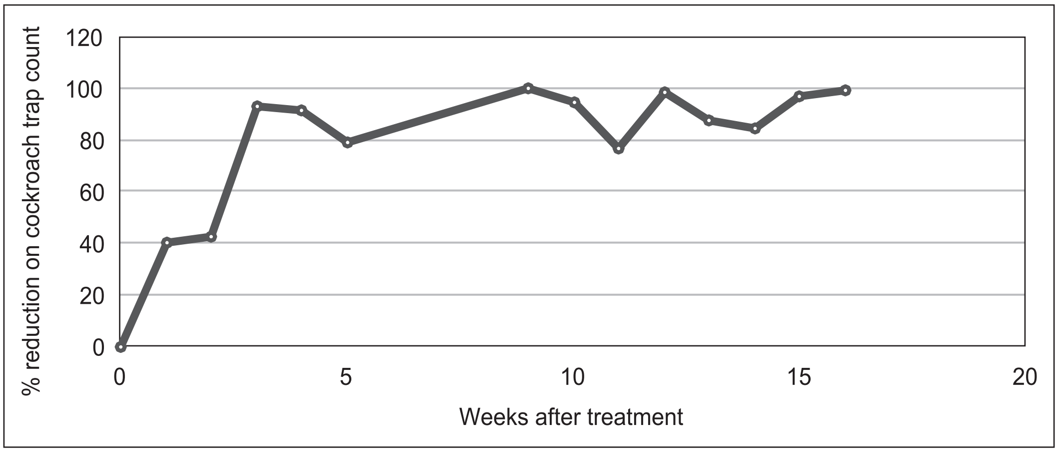

Figure 3. Progress of percentage reductions of mean German cockroach trap counts throughout the 16 weeks of biorational treatment for "house building F"

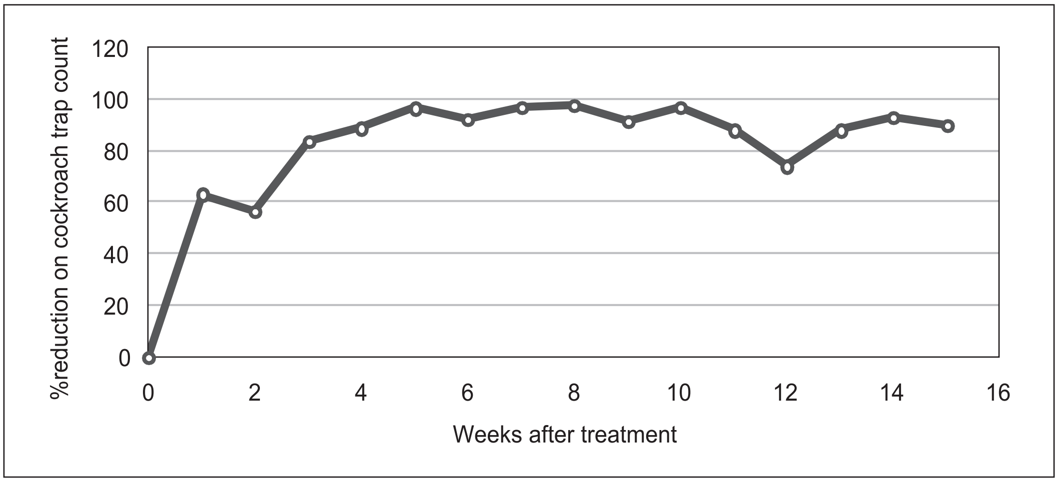

Figure 4. Progress of percentage reductions of mean German cockroach trap counts throughout the 15 weeks of biorational treatment for "hospital C"

weeks) respectively. To compare study locations, percentage reductions for similar treatment periods should be calculated. Mean corrected percentage reductions during a similar period treatment (15 weeks) were 72.11%, 72.56%, 85.71% and 88.1% for girls' and boys' dormitory, house building and hospital respectively. This shows that the mean of percentage reductions (corrected) for residential buildings during 15 weeks treatment was 76.79% and this was lower than the reduction in the hospital (88.1% during 15 weeks). However, the mean of infestation rate for the hospital (mean pre-treatment count, Table 3) was the lowest in comparison to other study locations.

Field efficacy of 2% hydramethylnon on the German cockroach varies with the strains in other studies. Lee (1998) reported 80% reduction of German cockroaches in a food outlet in Malaysia after three months of treatment, while Khadri (2000) reported a 64% reduction within two months of treatment. A 70% reduction within three months of

Table 3. Percentage reductions of German cockroach trap count upon mean of all post-treatment counts for two groups (Mean±SEM)

Study Locations	Treatment period (wk)	Treatments	n	Pre count (Mean)[1]	Post count (Mean)[2]	Mean % reduction post count[3]
Girls' dormitory G	26	Intervention	11	16.69±6.2a	1.3±0.33a	85.6±4.9a
		Control	12	15.16±4.2a	5.1±1.07b	38±16.1b
Boys' dormitory I	29	Intervention	17	19.82±7.00c	1.05±0.28c	84.59±3.49c
		Control	10	12.1±4.32c	3.09±0.93d	44.95±15.02d
House building F	16	Intervention	6	10.5±3.62e	1.39±0.38e	83.38±4.48e
		Control	4	3.58±0.72e	7.17±1.77f	-112.44±61.53f
Hospital C	15	Intervention	26	4.23±1.18g	0.45±0.25g	86.28±6.96g
		Control	15	2.84±1.95g	0.91±0.40g	57.60±14.90h

Means within column followed by the same letter are not significantly different at p=0.05, Mann-Whitney test or t-test related to exploratory analysis

[1] G: t=0.09, p=0.92 on $\log_{10}$ (mean+1) transformed data; I: t= -0.49, p=0.63 on $\log_{10}$ (mean+1) transformed data; F: t=1.517, p=0.168; C: (Median=3.33 & 2.84) w=8, z=-0.333, p=0.74

[2] G: t=4.32, p=0.01 on $\log_{10}$ (mean+1) transformed data; I: (Median=0.74 & 1.84) U=43, z=-2.109 p=0.03; F: t=-3.915, p=0.004; C: (Median=0.17 & 0.91) w=23, z=-1.333, p=0.18

[3] G: (Median=91.1 & 56.5) U=17, z=-3.02, p=0.003; I: (Median=88.6 & 52.2), U=38, z=-2.360, p=0.018; F: t=3.174, $p_{(1\text{-tailed})}$=0.025; C: (Median=94.15 & 57.6) w=4, z=-1.667, $p_{(1\text{-tailed})}$=0.048

treatment was reported in Thailand (Sitthicharoenchai *et al.*, 2006) and a 50% reduction after two months was reported in the USA (Appel, 1992). Earlier, Milio *et al.* (1986) reported a 78% to 97% reduction of German cockroach infestation, 2 to 4 months after hydramethylnon treatment, respectively. In the study conducted, with long periods of treatment for various locations, percentage reductions were within the range of the above mentioned studies. The high reduction among residential buildings after 15 weeks treatment (85.7% reduction) was related to 'house building F' with the least infested units (60% of units) and infestation rate (10.5 cockroaches per trap per unit) before treatment; while the least reduction from the same type of locations (residential buildings) and durations was related to 'girls' dormitory G' with the most infested units before treatment.

Percentage of recoveries for infested sites to achieve clean level of infestation after a 15 to 29-week treatment period are recorded in Table 2. These results showed 59-91% recovery for the residential buildings and 83% for the hospital. The remainder of infested units were in "low" to "moderate" levels of infestation. Survey of intervention units using the cockroach index after a similar treatment period (15 weeks) showed a mean of 84% recovery to achieve clean level for the residential buildings (91%, 94% and 67% for dormitories G, I and house building F respectively) and 83% for the hospital. All remaining units were in low level of infestation. However the dormitories with a mean of 92.5% recovery showed the most recovery for infested units. These results were higher than the 51.6% recovery following the 6-month intervention reported by Brenner *et al.* (2003). Wang & Bennett (2006) reported one apartment had a high level of cockroach infestation (>12 cockroaches) 29 weeks after intervention.

Analyses by linear regression of the mean of cockroach trap counts before and weeks after treatment for the two groups are shown in Table 4. The correlation between cockroach trap counts and weeks before and after treatment for intervention groups was simple linear with a specific negative slope for all study locations. However, there was no correlation between these data for the control groups of all study locations throughout the study period. Thus, the result showed that only the gel treatment had a significant reduction (note

Table 4. Regression coefficients for linear regression of mean of cockroach trap before and weekly duration of post-treatment count

Surveyed location	Treatment	n	Slope ±SE	Intercept ±SE	r^2	F	P
Girls' dormitory G	Intervention	11	-0.053±0.014	0.83±0.132	0.61	14.06	0.005**
	Control	11	-0.023±0.011	0.83±0.100	0.35	4.85	0.055
Boys' dormitory I#	Intervention	9	-0.95±0.262	10.642±2.1	0.653	13.164	0.008**
	Control	9	-0.208±0.353	9.898±2.834	0.047	0.345	0.575
House building F#	Intervention	14	-0.038±0.011	0.682±0.109	0.494	11.703	0.005**
	Control	14	0.014±0.011	0.738±0.105	0.120	1.629	0.226
Hospital C	Intervention	16	-2.833±1.112	9.573±1.304	0.317	6.487	0.023*
	Control	16	-1.035±1.310	8.619±1.86	0.043	0.624	0.443

* Significant linear correlation
** More significant linear correlation
# Transformed data by Log_{10} mean+1

the negative slope) in cockroach trap catch during the weeks of treatment. Appel (1990; 1992), Appel & Benson (1995), Appel & Tanley (2000) and Lee & Yonker (2003) showed field effectiveness of baits' performance on cockroaches by negative slopes for regression analysis of trap catch data.

Therefore, this study showed that biorational control approach using hydramethylnon gel bait together with educational programmes and sanitation, successfully managed the German cockroach infestation to reach a clean level of infestation, especially in residential buildings.

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