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The role of sanitation in the control of German cockroach (*Blattella germanica* L.)

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ABSTRACT

Seven different treatments consisted of four single applications and three combinations were applied to study the effect of sanitation on the control of the German cockroaches, namely: sanitation, lambda-cyhalothrin 2.5% CS, boric acid dust, imidacloprid 2.15% gel bait, combination of sanitation and lambda-cyhalothrin 2.5% CS, combination of sanitation and boric acid dust, and combination of sanitation and imidacloprid 2.15% gel bait. After 12 weeks, the highest cockroach catch reduction was obtained when using boric acid dust (94.4%), then sanitation and boric acid treatment (93.4%), followed by sanitation and lambda-cyhalothrin (82.5%), sanitation and imidacloprid 2.15% gel bait (77%), imidacloprid gel bait (54.8%), sanitation (17.6%) and finally lambda-cyhalothrin (-31.1%). This result indicates that sanitation has improved the effect of both the liquid spray and the gel and that boric acid seems to have a long residual effect since the top two treatments include boric acid.

Key words: Sanitation, German cockroach, *Blattella germanica*.

INTRODUCTION

Cockroaches are among the most common insects. They are found in nearly all parts of the world. The massive movement of people and supplies throughout the world has increased the possibility of introducing more pest cockroach species from other countries. Most of the major species are now found throughout the world wherever humans live. They are considered by some of the biologists to be one of the most adaptable and successful group of animals (Bennett *et al.* 1997).

Cockroaches are capable of transmitting many pathogens including bacteria, viruses, fungi, protozoa, and pathogenic helminthes that threaten human health. They act as potential transmitters of agents of bacterial diarrhea and nosocomial infection in hospitals (Agbodaze and Owusu 1989, Fotedar *et al.*1991, Vythilingam *et al.*1997). In addition, cockroaches not only spoil food but cause allergic reactions and psychological distress (Brenner1995).

Sanitation and good hygiene practices in homes and properties are essential for restricting cockroach populations, but when infestations become a problem there are no realistic alternatives to the use of insecticides. (Bennett et al 1997)
Low levels of sanitation and clutter provide more food, water, and harborages to cockroaches. These conditions favor the growth and survival of cockroach populations. Sanitation condition is correlated with cockroach populations (Wright 1979, Schal 1988).

Sanitation also is closely correlated to the control result because cockroaches can avoid contacting insecticide dust or spray or feeding on insecticide bait (Gupta *et al.* 1973, Schal 1988, Lee and Lee 2000).

Control of German cockroach by use of chemical insecticides has a long history going back to at least the early of this century (Mallis 1969).

The main insecticide groups that are currently being used for cockroach control are the organophosphates, carbamates and pyrethroids (Koehler and Patterson 1988, Reierson *et al*. 1988, Rust and Reierson 1978. Schal 1988). Chemicals in several other classes are also being used to a lesser extent (Fisher 1990).

In recent years, chemists have become increasingly aware of the fascinating versatility of boron compounds, some of them remarkably complex for inorganic compounds, and the wide range of their application in industry (Borax review 1988).

Boric acid is often recommended because of its low mammalian toxicity (Ebeling1975, Piper and Frankie 1978a, Slater *et al*. 1979).

Baits are starting to gain wide acceptance in the management of cockroaches (Reierson 1995). Gel bait formulation may be more effective than dry baits (Denzer *et al*. 1988).

Gel baits can be selectively used in sensitive areas, such as premises used for the preparation of food, hospitals and kindergartens (Benson and Zungoli, 1997).

Application of insecticidal baits is one of the most common and effective strategies for controlling the *B. germanica* (Reierson 1995, Bennett *et al.*1997). Toxic baits are commonly used in urban pest and management programs and provide several advantages over other insecticide application methods.

Since basic studies on the role of sanitation and other control measures in controlling cockroaches in Saudi Arabia are still lacking, and to date, no any study as such have been published. This study was conducted to evaluate the role of sanitation in the German cockroach program.

MATERIAL AND METHODS

Study area and duration

The study was carried out in a residential compound in an urban area at Al-Ajwad district in east of Jeddah city from September 2007 to January 2008.

Houses selected were similar in area (50 m^2 each). Each house had kitchen, hall, two rooms (bed and dinning), and bathroom.

Cockroach density was estimated in all houses of the compound. Of the 76 similar houses included initially, 48 had high cockroach infestation. Of these 28 houses were selected for sanitation and chemical treatments by simple random sampling method. Seven treatments were applied and each treatment was replicated in four randomly selected houses.

Treatments applied were: sanitation, lambda-cyhalothrin 2.5% CS, boric acid dust, imidacloprid 2.15% gel bait, combination of sanitation and lambda-cyhalothrin 2.5% CS, combination of sanitation and boric acid dust, and combination of sanitation and imidacloprid 2.15% gel bait.

Residents cooperation

The individuals whose houses were selected for the seven control treatments were briefed about the study to get their full cooperation and participation. The precaution to be followed post-treatment in the treated houses were explained to the concerned residents and it was ensured that the same were complied with during the entire trial period.

Pre-treatment assessment in field

In every house included in the study, 5 sticky traps were placed around each of the usual harborages of cockroaches (stove, fridge, under the sink, bathroom, and dinning room). Traps were removed next morning to estimate the average cockroach density for every house.

Post-treatment density

Post-treatment density was assessed for

every house by placing the sticky traps in the same cockroach harborages of pre-treatment. The assessment was done at two, four, eight and twelve weeks after application of control measures. The percentages reduction of cockroach infestation in the respective houses were calculated using the following formula:

$$\% \text{ Reduction} = \frac{\text{Counts of pre-treatment - Counts of post-treatment}}{\text{Counts of pre-treatment}} \times 100$$

Sanitation

Residents whose houses were selected for sanitation treatment were taught to thoroughly clean areas beneath cabinets, sinks, stoves, refrigerators, etc. as well as, cupboards, pantry shelves and food storage bins. Clean up spilled foods and liquids. They were asked to avoid leaving scraps of food on unwashed dishes and countertops overnight. In addition, they have been instructed to keep food in tightly sealed containers, rinse cans and bottles before putting in the trash, and transfer garbage outdoors every night into roach-proof receptacles away from the house.

Residents were briefed how to inspect for cockroaches and their egg cases in sacks, cartons, boxes, used appliances and furniture, etc., brought into the home, because infestations are usually initiated through the introduction of infested materials.

Some structural modifications such as caulking holes in walls where pipes pass through are necessary in the kitchen, bathroom, and other areas of the house were requested from the residents in houses selected for sanitation treatment in order to control German cockroaches.

Lambda-cyhalothrin 2.5% CS

The chemical used was Lambda-cyhalothrin 2.5% CS (Demand) in a form of Capsulated Suspension (CS), Syngenta, Switzerland.

Lambda-cyhalothrin 2.5% CS was applied at a rate of 50ml per 5 litre water. The residents were required to empty all cabinets and closets. Once the residents had left the houses, a through insecticide treatment with Lambda-cyhalothrin 2.5% CS was applied with a B&G sprayer system operated at 1.4 kg/cm2 (20psi) with a fan spray nozzle .

The spray was applied to areas around kitchen cabinets, closets, appliances, and toilet facilities and on all baseboards, door and window frames and moldings. In addition, insecticide was directed into cracks and crevices in the kitchen, dinning room, and bathroom, as well as, any additional areas of the house specified by the residents.

Boric acid dust

Chemical used was orthoboric acid dust 99.90% (H_3BO_3) min., produced by Inkobar Company, Peru.

Boric acid dust was applied lightly (thin layer), by using a hand duster in: cracks and crevices of clothes closet shelves, hollow legs of chairs and tables, and wall or floor cracks and crevices throughout the house. Boric acid dust was lightly spread under the sink, in the dead space between the sink and wall, and around utility pipes. Also along the back edges and in corners of shelves in cabinets, cupboards, under/behind the refrigerator, stove, into the opening where plumbing pipes enter walls (such as behind the shower and washing machine), into openings around drainpipes and electrical conduits.

Imidacloprid 2.15% gel bait

Chemical used was Imidacloprid 2.15% gel bait, Bayer AG Leverkusen, Germany.

Imidacloprid 2.15% gel bait (single application at 0.1 gel spots of 2-3 per linear meter) was used in the selected houses at the primary harborages such as the cabinet, under the kitchen sink, and around the stove and refrigerator (Appel and Reid 1992, Lund and Bennett 1978). In addition, gel spots were placed at floor–wall junctions, in corners, next to cracks and crevices (Ebeling *et al.*1966, Ebeling and Reierson 1974a, Ebeling 1991). Other treated sites included lower kitchen cupboards, upper kitchen cupboards, the infested sites and potential harborages in the bathrooms and dinning rooms.

Combination of sanitation and Lambda-cyhalothrin 2.5% CS, sanitation and boric acid dust and sanitation Imidacloprid gel

In the houses selected for the combination of sanitation and the three formulations, the residents were briefed about sanitation requirements daily needed in their houses as mentioned before. In addition, the three formulations were applied in the same manner as described previously.

Statistical analysis

Data was statistically analyzed by using SAS (2001) software program.

RESULTS

The effect of sanitation on the population of *Blattella germanica*

The effect of sanitation on the population of *B. germanica* is presented in table (1) and Fig.(1). The statistical analysis indicated that there were no significant differences between all the post treatment cockroach counts when compared to the 24 hours pretreatment counts ($P < 0.05$). Similarly, when the post-treatments counts of the cockroaches were compared with each other they showed no significant differences among them ($P < 0.05$).

Table 1: The effect of sanitation on Cockroach population

Intervals	Mean* ± Std Error	% Reduction
24 hours before treatment	32.75 ± 20.4994[a]	0.00
2 weeks after treatment	22 ± 12.7148[a]	32.8
4 weeks after treatment	10 ± 4.6007[a]	69.5
8 weeks after treatment	9 ± 4.1432[a]	72.5
12 weeks after treatment	27 ± 17.9351[a]	17.6
	LSD = 41.372	

*Number of cockroaches per house.

Means with the same letters are not significantly different LSD = Least Significant Difference

Table 2: The effect of sanitation on the performance of lambda-cyhalothrin

Intervals	Treatments			
	Lambda-cyhalothrin (Mean*± Std.Error)	% Reduction	Lambda-cyhalothrin + sanitation (Mean*± Std.Error)	% Reduction
24 hours before treatment	30.5 ± 18.2414 [a]	0.00	34.25 ± 20.8741 [a]	0.00
2 weeks after treatment	8.25± 6.2899 [a]	73	5.75 ± 3.6600 [a] b	83.2
4 weeks after treatment	9.25 ± 2.4958 [a]	69.7	2.75 ± 1.7500 b	92
8 weeks after treatment	21.25 ± 8.6639 [a]	30.3	4 ± 1.5811 b	88.4
12 weeks after treatment	40 ± 10.2551 [a]	- (31.1)	6 ± 0.9129 a b	82.5
	LSD =31.866		LSD = 28.771	

*Number of cockroaches per house.

Means with the same letters are not significantly different

LSD = Least Significant Difference

However, the percentages reduction of *B. germanica* over time when compared to the pretreatment counts (mean = 32.75) revealed that there was a gradual reduction in the population of *B. germanica* at week two, week four, and week eight, after treatment (32.8%, 69.5%, and 72.5% respectively), whereas the percentage reduction at week twelve after treatment declined to only 17.6% indicating an increase in the population of *B. germanica* at this period. The best performance of sanitation was obtained at week eight after treatment.

The effect of sanitation when combined with lambda- cyhalothrin 2.5% CS on the population of *Blattella germanica*

Table (2) and fig (2). summarize the comparison between the efficacy of the liquid spray used alone and when combined with sanitation. At all the post-treatment counts the introduction of sanitation has increased the percentage reduction in the of the German cockroach population. The percentage reduction has increased in two weeks after application from 73% to 83.2%, in four weeks from 69.7% to 92% in eight weeks from 30.3 to 88.4% in twelve weeks from (-31.1) to 82.5% .

Table 3: The effect of sanitation on the performance of boric acid dust

Intervals	Treatments			
	Boric acid (Mean*±Std.Error)	% Reduction	Boric acid + Sanitation (Mean*±Std.Error)	% Reduction
24 hours before treatment	35.75 ± 17.1385 [a]	0.00	34 ± 10.7160 [a]	0.00
2 weeks after treatment	1.25 ± 0.9465 b	96.5	3 ± 0.4082 b	91.2
4 weeks after treatment	4.25 ± 2.9826 b	88.1	1.25 ± 0.4787 b	96.3
8 weeks after treatment	2.75 ± 0.9465 b	92.3	2.5 ± 1.2583 b	92.6
12 weeks after treatment	2 ± 0.7071 b	94.4	2.25 ± 1.2500 b	93.4
	LSD =23.539		LSD = 14.667	

*Number of cockroaches per house.

Means with the same letters are not significantly different

LSD = Least Significant Difference

Table 4: The effect of Sanitation on performance of Imidacloprid gel

Intervals	Treatments			
	Imidacloprid gel bait (Mean*±Std.Error)	% Reduction	Imidacloprid gel bait + Sanitation (Mean*±Std.Error)	% Reduction
24 hours before treatment	31.5± 18.7194[a]	0.00	33.75 ± 16.903[a]	0.00
2 weeks after treatment	13 ± 5.5528[a]	58.7	1.5 ± 0.2887 b	95.6
4 weeks after treatment	5.25 ± 2.0156[a]	83.3	0.25 ± 0.2500 b	99.3
8 weeks after treatment	4.5 ± 1.7078[a]	85.7	0.75 ± 0.4787 b	97.8
12 weeks after treatment	14.25± 8.4001[a]	54.8	7.75 ± 2.4958 b	77
	LSD =28.874		LSD = 23.049	

*Number of cockroaches per house.

Means with the same letters are not significantly different

LSD = Least Significant Difference

Counts of *B. germanica* when using sanitation with the liquid spray indicated a significant difference among the post treatments counts at the 4 intervals compared to the 24-hour pretreatment counts ($P > 0.05$).

The results indicated that sanitation has improved the performance of the spray formulation throughout the twelve weeks control period and the level of reduction in the cockroach population was always above 80% and no recovery of the suppressed cockroach population has occurred.

The effect of sanitation on the performance of boric acid dust

The results in table (3) and fig. (3) revealed no apparent difference between applying the boric acid alone or together with sanitation.

The trap catch of *B. germanica* showed a significant difference between all the post-treatment counts when compared to the 24h pretreatment trap catch ($P > 0.05$).

However, when the post treatment counts were compared with each other, no significant difference was found ($P < 0.05$).

The higher percentage reduction in the post-treatment cockroach counts when compared with the pretreatment counts was 96.3 % reduction obtained at week four after treatment followed by week twelve (93.4%,), then week eight (92.6 %5), and finally week two with a 91.2%, reduction.

It also worth mentioning that the percentage reduction post-treatment remained almost stable above 90% level throughout the twelve weeks.

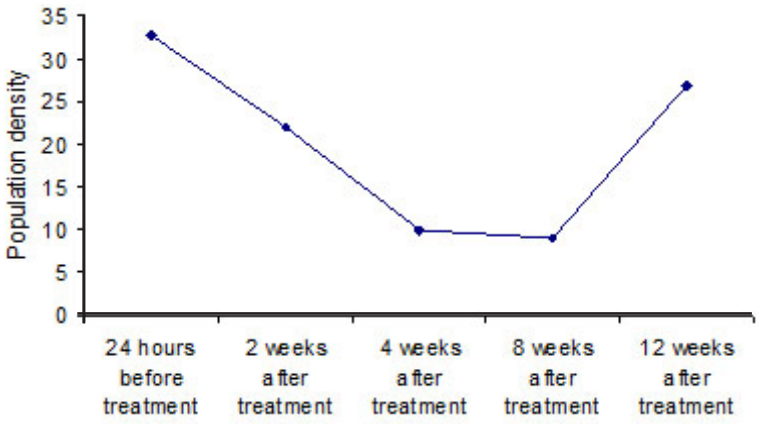

Fig. 1: The effect of sanitation on cockroach population

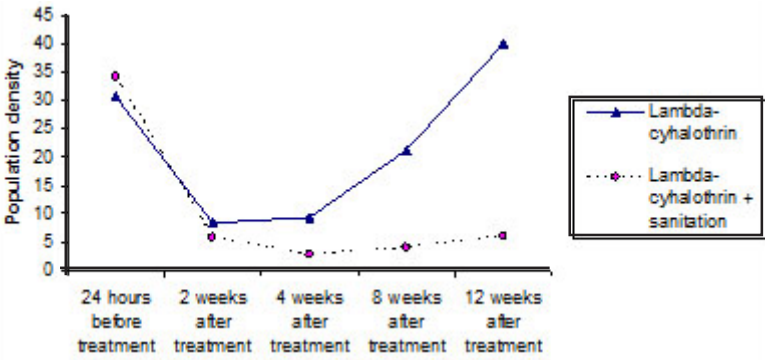

Fig. 2: The effect of sanitation on performance of Lambda-cyhalothrin

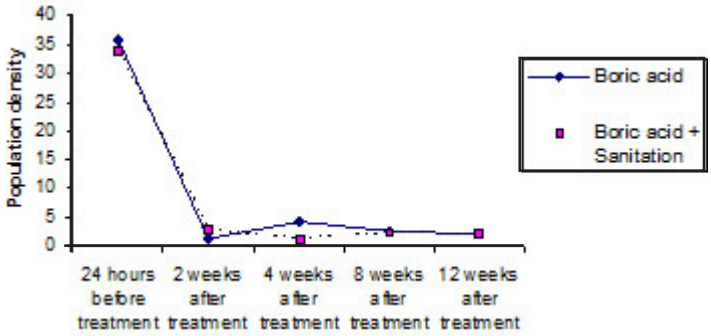

Fig 3: The effect of sanitation on the performance of boric acid

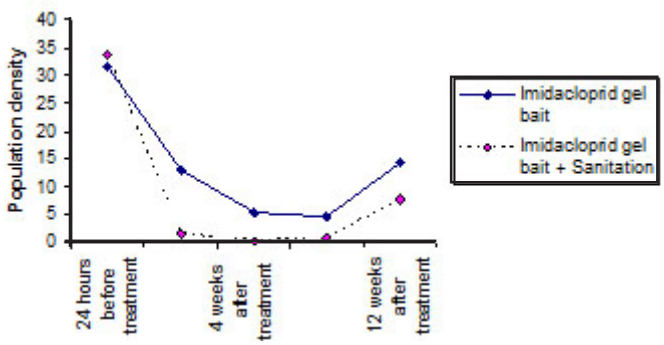

Fig. 4: The effect of Sanitation on performance of Imidacloprid gel

The effect of sanitation on performance of Imidacloprid gel bait

The results in table (4) and fig. (4) indicated that throughout the experiment, the combination of sanitation and the gel gave better reduction percentages than when using the gel alone.

A significant reduction in *B. germanica* population was obtained at all the post-treatment counts at the different intervals when compared to the 24h pretreatment counts ($P > 0.05$). Nonetheless, the four post-treatment counts of cockroaches when compared to each other reflected no significant difference ($P < 0.05$).

The best performance of (sanitation + Imidacloprid 2.15% gel bait) when compared to pretreatment counts was obtained at week four with (99.3. %) reduction in population counts, then week eight (97.8%), followed by week two (95.6%), and finally week twelve when the reduction fell to only (77%).

Sanitation enhanced the efficacy of the gel and reduced the population recovery observed when applying the gel alone.

DISCUSSION

When conducting control measures against German cockroaches**,** the houses having high infestation were found to be poor in environmental sanitation. The common hiding places in the study areas were stoves, refrigerators, under the sinks, under cabinets, washing machines, and water pipes.

The infestation in the houses was primarily of German cockroach *Blattella germanica.*

The results of the effect of sanitation singly on the population of German cockroach indicated no significant effect throughout the experiment period. (table 1 and Fig.1).

This could be due to the fact that sanitation has more effect on preventing establishment of infestations than in reducing existing populations. When the cleanliness is improved, there it may not be drastic effect on the existing cockroaches because they will continue to live for a considerable period of time. It may therefore be more appropriate to say that the role of sanitation is to limit rather than control infestations (Milligan 1984).

Lee and Lee (2000) also found that sanitation has been shown not to have a direct relationship with the level of domiciliary cockroach infestation in Malaysia.

An obstacle in the utilization of sanitation is the difficulty in establishing acceptable sanitary standards. Residents cannot be asked to keep their premises "clean" since this word is interpreted differently by each person. Which areas to clean and how often must be clearly laid out. Bennett (1978) reported criteria for rating sanitation of residences; however, the values of his categories are greatly diminished by their subjectivity (Milligan 1984).

The results of sanitation seen in treated houses in Jeddah province are similar to those of Owens (1980) who used commercial services to increase the sanitary level of apartments, but was unable to reduce the population levels significantly. Results are also similar to those obtained by Milligan (1984).

The reason for that can be explained by the fact that virtually no situation exists indoor where cockroaches food in some form is not available (Marsh and Bertholf 1986). Therefore, proper storage of food and sanitation in kitchens and bathrooms will not starve cockroaches.

Once German cockroach populations are established, it can be impossible to reduce the population by sanitation alone (Owens 1980*;* Bertholf 1983). Other control methods must be integrated into the control program for significant population reduction.

The use of Lambda- cyhalothrin 2.5% CS singly to control German cockroach in this study did not result in a significant reduction of the insect populations. The best performance of the chemical was noticed at week two which may be due to the fast knockdown effect of the liquid formulation (table 2). At week twelve, the cockroach population witnessed more than 30% increase indicating a recovery of the suppressed population even more than the respective pretreatment levels.

The relatively low percent reduction in German cockroach populations through the 12 weeks of this study is similar to other control failures in some field population that have been reported by Cochran1989, Scott *et al.* 1990, Atkinson *et al.*1991, Valles and Yu 1996, Dong *et al.* 1998, Valles 1999, Valles *et al.* 2000, Wei *et al.* 2001.

Vythilingam *et al.* (1997) carried out Control measures using lambda cyhalothrin against American cockroach (*Periplaneta americana*) and Smoky brown cockroach (*Periplaneta brunnea*) found that there was no significant difference between treated and control sites.

In this study, boric acid significantly reduced the population of the German cockroach throughout the twelve weeks, and the higher percentage reduction was obtained at week two post-treatment (96.5 %,), (table 3). This may be explained by the fact that there were more cockroaches that encountered the dust in the treated areas (the mean of the pretreatment cockroach counts were 43.75) resulted in more cockroaches being affected and died by the insecticide at this period. While the percentages reduction achieved at week four were (88.1%), week eight (92.3%), and week twelve (94.4%) indicating a gradual suppression in the cockroach population towards the end of the experiment (Fig.3). In addition, it suggests the long residual effects of boric acid over time.

The results of the combination between sanitation and lambda- cyhalothrin 2.5% CS in table (2), and Fig.(2) indicated that sanitation has improved the performance of the spray formulation throughout the twelve weeks control period and the level of reduction in the cockroach population was always above 80% .

Similarly, sanitation enhanced the efficacy of the imidacloprid gel and reduced the population recovery observed when applying the gel alone (table 4 and Fig 4).

When applying boric acid dust singly or in combination with sanitation, it was observed that the percentage reduction post-treatment remained almost stable above 90% level throughout the twelve weeks (Fig.3and table 3).

When sanitation is integrated with other control strategies, such as residual treatments and baits, cockroaches are more likely to contact insecticide residues since they have to spend more time foraging for food and water (Schal and Hamilton 1990). In addition, Schal (1988) found greater efficacy of the pyrethroid cypermethrin in clean rather than cluttered, greasy apartments.

An important factor that has been reported to affect bait performance against German cockroaches in the field is sanitation (Christensen 1991).

Lee and Lee (2000) reported that chlorpyriphos bait stations placed in houses with moderate and poor sanitary conditions generally took longer to achieve the level of effectiveness that was observed in houses with good sanitary conditions.

This may indicate that cockroaches in houses with these conditions took a longer time to locate the baits due to availability of competitive food. These data suggest that sanitation affected the effectiveness of baits in the field.

As the cockroach forages for food materials solely by chance (Reierson 1995), the presence of food debris and other clutter in houses with moderate and poor sanitary conditions is a competing factor to the attractiveness of bait material. In addition, under good sanitary conditions, cockroaches may be stressed with starvation and dehydration due to lack of food and water sources. This might encourage cockroach foraging and dispersal (Bertholf 1983) and thus the chance of cockroaches coming into contact with the bait will increase. Furthermore, under starved conditions, cockroaches become more susceptible to insecticide action (Lee *et al*. 1996b**,** Lee and Heng 2000).

Good sanitation practice is essential for better control of cockroaches using baiting and other application methods (Lee and Lee 2000).

Gupta *et al.* (1973, 1975) reported that insecticide applications (spraying and dusting) were more effective against German cockroaches in apartments with better sanitation. Lee (1998) also emphasized the importance of good sanitation when baiting against insecticide-resistant German cockroaches in food-outlets.

CONCLUSION

This study has successfully demonstrated that sanitation influenced the performance of other control strategies, such as residual treatments and baits, by significantly enhance the performance of those control measures. Therefore, it is highly recommended when applying the different control measures against German cockroach to include sanitation practices in order to obtain best results.

Boric acid proved to have an excellent efficacy on the cockroaches, and all treatments including this chemical gave a highly significant suppression of the cockroaches over a longer period of time. It is therefore, recommended to be used in any control programs against cockroaches.

This study demonstrated clearly that combinations of more than one control method against German cockroach are more effective and better than using a single one.

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