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Research

Integrated pest management of the German cockroach (Blattodea: Blattellidae) in manufactured homes in rural North Carolina

Beatrice N. Dingha[1,], Jeremy O'Neal[2], Arthur G. Appel[3], and Louis E. N. Jackai[2]*

Abstract

The German cockroach, *Blattella germanica* (L.) (Blattodea: Blattellidae), is a serious pest in residential housing with control administered mainly through application of pesticides. Integrated pest management (IPM) involves a combination of strategies aimed at reducing pest populations. Over a 27 mo study period, we determined levels of German cockroach populations in rural manufactured residential homes: before IPM implementation (Pre-IPM), the period when residents were educated on IPM strategies (IPM-education), and during education and insecticide application (IPM-education plus bait). Sanitation level in the IPM-education phase (2.8) was significantly different from that in the Pre-IPM phase (3.9) and was accompanied by a decrease in trap catch. Sticky and jar traps were deployed in kitchen areas to assess levels of infestation. Trap catch from all participants during the 3 phases was significantly different. Mean cockroach catch per participant per trap was 20.5 ± 4.1 during Pre-IPM, 13.2 ± 2.2 during IPM-education, and 3.9 ± 0.7 during IPM-education plus bait treatment. During the last 3 mo of the study, the population level declined by 86% when compared with that during the Pre-IPM phase. Victor Roach® pheromone sticky traps captured more cockroaches (19.2 ± 1.9) than jar traps (7.2 ± 1.1), accounting for 73% of cockroaches captured. Traps caught more nymphs than adult cockroaches. Trap catch was unevenly distributed, with the highest (34%) catch occurring around refrigerators. We conclude that the inclusion of education of residents in German cockroach IPM programs will make implementation and sustainability of cockroach control more efficient.

Key Words: *Blattella germanica;* cockroach infestation; IPM

Resumen

La cucaracha alemana, *Blatella germanica* (L.) (Blattodea: Blattellidae), es una plaga seria en viviendas residenciales bajo un control administrado principalmente basado en la aplicación de plaguicidas. El manejo integrado de plagas (MIP) implica una combinación de estrategias dirigidas a reducir las poblaciones de plagas. Durante un período de estudio de 27 meses, se determinaron los niveles de las poblaciones de cucarachas alemanas en los hogares residenciales fabricados en áreas rurales: antes de la implementación del MIP (Pre-MIP), el período en que los residentes fueron educados en las estrategias de manejo integrado de plagas (MIP-educación), y durante la educación y la aplicación de insecticida (MIP-educación y cebo). El nivel de sanitación en la fase de MIP-educación (2,8) fue significativamente diferente de la de la fase de pre-MIP (3.9) y fue acompañado por una disminución de la captura trampa. Trampas pegajosas y de envases fueron puestas en las áreas de la cocina para evaluar el nivel de infestación. El número de cucarachas capturas en las trampas de todos los participantes durante las fases 3 fue significativamente diferente. La media de la captura de cucarachas por participante por trampa fue de 20,5 ± 4,1 durante la pre-MIP, 13,2 ± 2,2 durante educación-MIP y 3,9 ± 0,7 durante educación-MIP más el tratamiento con cebo. Durante los últimos 3 meses del estudio, el nivel de población disminuyó en un 86% si se compara con la que durante la fase de pre-MIP. Las trampas de feromonas Victor Roach® capturaron más cucarachas (19,2 ± 1,9) que las trampas de envase (7,2 ± 1,1), que representan el 73% de las cucarachas capturadas. Las trampas atraparon más ninfas que las cucarachas adultas. La captura en las trampas fue distribuida de forma desigual, con la captura más alta (34%) ocurriendo alrededor de los refrigeradores. Llegamos a la conclusión de que la inclusión de la educación de los residentes en programas de MIP para la cucaracha alemana hará más eficiente la implementación y sostenibilidad de control de las cucarachas.

Palabras Clave: *Blatella germanica*; infestación de cucarachas; MIP

The German cockroach, *Blattella germanica* (L.) (Blattodea: Blattellidae), is a common indoor pest in many homes and buildings, including low-income residential housing. The cockroaches' indiscriminate movement between filth and food make them potentially efficient vectors of human pathogens (Alcamo & Frishman 1980; Brenner et al. 1987). The presence of the German cockroach in homes can also cause

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psychological distress, elicit allergic reactions, and trigger asthma attacks as a result of the presence of allergens in fecal matter and exuviae (Brenner 1995), which can be inhaled or acquired through direct contact. According to the U.S. Department of Housing and Urban Development (2004), cockroach allergens are excessively found in 30 to 50% of inner city housing, and affect 5 to 15% of the population. High cockroach population densities are positively correlated with high allergen levels (Wang et al. 2008). Control strategies that reduce cockroach populations without posing health hazards to residents are important and necessary, because they will reduce cockroach allergen levels and, presumably, the incidence of asthma as well (Arbes et al. 2003, 2004).

Insecticides are the major tool used by professionals and residents for German cockroach control (Koehler et al. 1995). In a 2012 survey we conducted in rural North Carolina, 71% of the respondents indicated management of German cockroach infestations required routine applications of pesticides either by a member of their household or a pest control professional (Dingha et al. 2013). Inappropriate use of pesticides in homes has been associated with several health effects, including headache and nausea (Titli et al. 2008) and skin and eye irritations (Graham et al. 2005).

Integrated pest management (IPM) is a proven method of pest control that seeks to mitigate the impact of pests, delay development of insecticide resistance, curb environmental contamination, and minimize human health risks (Pedigo & Rice 2009). In the case of the German cockroach, this may be achieved through the use of strategies such as education, sanitation, trapping, vacuuming, and sealing of harborages with pesticides applied as needed (Kardatzke et al. 1981; Frishman 1995; Robinson & Zungoli 1995; Kaakeh et al. 1997). Overall, pesticide usage is reduced and the associated risks are minimized by using pesticides that are of low mammalian toxicity. In addition, the use of non-spray formulations such as baits and gels in confined areas is encouraged, because it reduces the probability of human exposure. Several studies have demonstrated the greater effectiveness of IPM strategies compared with a pesticide spray–only tactic (Kramer et al. 2000; Miller & Meek 2004; Wang et al. 2006; Williams et al. 2006). There also is ample evidence on the reduction of German cockroach allergens by using IPM strategies that include baiting (Arbes et al. 2003, 2004; Sever et al. 2007).

This success notwithstanding, IPM for cockroach control does not have a high adoption rate in manufactured homes especially those in rural communities. Instead, most studies on German cockroach IPM programs have focused primarily on low-income and public apartment homes in the inner cities in the United States (Wood 1980; Robinson & Zungoli 1985; Hedges 1994; Campbell et al. 1999; Kitch et al. 2000; Leaderer et al. 2002; Brenner et al. 2003; Miller & Meek 2004; Morgan et al. 2004; Williams et al. 2006; Condon et al. 2007; Peters et al. 2007; Nalyanya et al. 2009; Juneau et al. 2011). We are not aware of any published study on IPM for German cockroach control in manufactured homes, even though there are about 8.7 million of them, which account for 6.3% of the 128.3 million housing units in the United States. According to the 2007 American Housing Survey (U.S. Census Bureau 2007), these homes house 17.8 million people. In North Carolina, 14% of the state's households live in manufactured homes with that percentage increasing in rural areas (U.S. Census Bureau 2008). From our survey of residents in rural North Carolina (Dingha et al. 2013), it is clear that there is need for effective and sustainable IPM education that targets household occupants who are responsible for pest management activities. In this study, we report on German cockroach infestations in low-income households living in manufactured homes in rural North Carolina during 3 intervention phases, namely: Pre-IPM intervention, IPM-education intervention, and IPM-education plus bait intervention. The impact of these phases on the population levels of the German cockroach was assessed over a 27 mo study period.

Materials and Methods

RECRUITMENT OF IPM PARTICIPANTS

From a survey conducted in 2010 and 2011 in Franklin, Warren, and Vance counties (rural) in the Piedmont region of North Carolina, 38% of residents were willing to participate in an IPM program (Dingha et al. 2013). As a follow-up to IPM implementation, they were contacted by phone and 10 agreed to participate. During the course of the project, data from 4 participants who were frequently unavailable during the scheduled weekly trap pickup were not included in the report. All 6 participants in the study reported here had a college or high school education and lived in Franklin County, North Carolina, in manufactured homes that they owned.

MONITORING OF THE GERMAN COCKROACH

From Oct 2011 to Mar 2014, cockroach population levels in 6 manufactured homes (identified only as A, B, C, D, E, and F) were monitored with Victor Roach® pheromone sticky traps (2.5 × 4.5 inches, i.e., 6.35 × 10.16 cm) (Model M327, EPA 47629-PA-01) (Woodstream, Lititz, Pennsylvania) and glass jar traps (0.95 L) baited with a piece of bread and peanut butter. The inside lip of the glass jar was coated with petroleum jelly to prevent cockroach escape. Ten sticky and jar traps were placed next to each other in the kitchen of each participant in the following areas: above and below cabinets, under sinks, and around stoves and refrigerators (Appel 1992). Traps were retrieved weekly and brought back to the laboratory, where cockroaches were counted and recorded as adults and nymphs caught per trap per location. As the traps were retrieved, they were replaced with fresh ones. Data collected from each home during the first 3 mo (Oct to Dec 2011) of the study served as an internal control.

WORKSHOP TO EDUCATE RESIDENTS

A workshop was organized in Jan 2012 for all residents and members of their households. They were given presentations on the biology, habits, and IPM strategies for German cockroach control. The workshop also emphasized the importance of sanitation and prevention, highlighting the need to eliminate excess food, water, and shelter or hiding places for cockroaches. Preventive measures discussed included sealing cracks and crevices with caulking to eliminate cockroach harborages. Participants were also educated on health-related issues such as asthma, which can be triggered as a result of the presence of German cockroach allergens in homes. At the end of the workshop, participants received handouts obtained from the Environmental Protection Agency's website on various topics including "Integrated Pest Management Principles" (https://www.epa.gov/safepestcontrol/integrated-pest-management-ipm-principles), "Pesticides and their Impact on Children: Key Facts and Talking Points" (http://purl.access.gpo.gov/GPO/LPS111647), "Effective Control of Household Pests" (https://www.epa.gov/sites/production/files/2015-08/documents/echp_english_100-f-04-009.pdf), "Do You Really Need to Use a Pesticide?" (https://www.epa.gov/safepestcontrol/do-you-really-need-use-pesticide), and "Managing Pests in Child Care Centers using IPM: Module 6, Managing Cockroach in Child Care Centers" (https://www.epa.gov/sites/production/files/documents/Module06.pdf). To ensure that resident education served prominently as part of an effective control strategy, weekly reminders were put into practice. For example, we demonstrated home keeping procedures to reduce clutter and remove trash and food residue. Throughout the Pre-IPM, IPM-education, and IPM-education plus bait phases during weekly visits, each kitchen was

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inspected and level of sanitation ranked (1–5) based on the general cleanliness, amount of clutter and of trash and food on floor, sink, and countertop. The ranking was (1) kitchen clean, no clutter, no trash and no food residue on floor, sink, and countertop; (2) kitchen clean, a little clutter, no trash, a little food residue on floor, sink, and countertop; (3) kitchen dirty, some clutter, trash and some food on floor, sink, and countertop; (4) kitchen dirty, a lot of clutter, a lot of trash and food on floor, sink, and countertop; and (5) kitchen extremely dirty, a lot of clutter, a lot of trash and food on floor, sink, and countertop. During the IPM-education and IPM-education plus bait phases, residents were reminded weekly during trap placement and removal of the importance of simple rules of sanitation: to avoid leaving food or water out overnight, to clean up spilled foods, including crumbs on the floor and countertop, and to take out trash.

BAIT APPLICATION

During the first 6 mo of the study, all live cockroaches (adults and nymphs) collected weekly from jar traps from individual homes were shipped to Auburn University, Alabama, where the susceptibility of the population from each home was determined for 5 insecticidal bait formulations. Cockroach mortality was determined in Ebeling choice boxes (Appel 1992). A minimum of 6 replicates with 10 adult male cockroaches each for $n = 60$ was used. Based on low LT50 values and 100% mortality within 7 d, Combat® Source Kill Max[R1] containing 0.03% fipronil in a dry bait formulation enclosed in small roach child-resistant bait stations was selected for use (Appel et al. unpublished). Bait stations were placed in the kitchen in areas alongside sticky traps as described for monitoring. Ten bait stations were applied in each kitchen, and the bait stations were replaced after 6 mo based on label recommendations.

STATISTICAL ANALYSES

Trap catch data were collected from Oct 2011 to Mar 2014 to compare the effectiveness of education and bait applications. Baseline data collected during the Pre-IPM intervention phase were compared with those collected during the IPM-education and IPM-education plus bait intervention phases to obtain percentage of reduction in trap catch. Comparisons of trap catches among the 3 intervention phases, and of monthly trap catch among participants and between trap types for the sampling period were also analyzed. German cockroach populations usually decline during winter and increase during the summer months. Percentage of change in trap catch at 3 mo intervals was compared with the Pre-IPM trap catch. To eliminate the effect of cold weather on German cockroach population levels, total trap catch during the Pre-IPM winter months was compared with catches (excluding those from residents who did not comply with simple sanitation practices) during the winter months of IPM-education and IPM-education plus bait intervention.

Data were evaluated using both parametric and non-parametric statistical tests. For the parametric method, cockroach counts were log (ln) transformed after adding 0.1 to each value to eliminate zero counts. The transformed data were analyzed using Proc GLM (SAS 9.3, SAS Institute 2012) analysis of variance; means were separated at $P \leq 0.05$ levels using Tukey's HSD test. Actual means are reported in the results. For the non-parametric analysis, Student's *t*- test was used to compare sanitation rankings during the Pre-IPM phase with those during either the IPM-education phase or the IPM-education plus bait phase.

Results

After continuous education of residents to implement good sanitation practices, there was a reduction in German cockroach populations. The difference in the mean sanitation ranking score in the Pre-IPM and IPM-education phases was significant ($t = 2.1$; df =1,5; $P = 0.017$), with a mean change of 3.9 to 2.8. This difference was accompanied by 67% reduction in trap catch. The sanitation level in the IPM-education plus bait when compared with the Pre-IPM phase improved from 3.9 to 2.0. This difference was significant ($t = 2.3$; df =1,5; $P < 0.010$) and was accompanied by 87% decrease in the German cockroach population.

Total numbers of cockroaches trapped monthly during the 27 mo study period were different ($F = 4.73$; df =1,26; $P < 0.0001$) with the highest trap catch (34.7 ± 9.7 per trap) recorded in Aug 2012 and the lowest (0.7 ± 0.4) in Mar 2014 (Fig. 1). Combined trap catches for each intervention phase were different ($F = 24.69$; df =1,2; $P<0.0001$). The mean cockroach catch was 20.5 ± 4.1, 13.2 ± 2.2, and 3.9 ± 0.7 per trap during the Pre-IPM, IPM-education, and IPM-education plus bait intervention phases, respectively. From Jun 2013 to Mar 2014, when insecticide was used in addition to education of residents (IPM-education plus bait), the population level decreased significantly (Fig. 1) with no capture in any trap in 50% of the participating households (B, C, and E) (Fig. 1). Throughout the entire study, more nymphs than adult cockroaches were caught each month (Fig. 1).

At 3 mo intervals after implementation of IPM-education, German cockroach population levels decreased steadily when compared with the trap catch during the Pre-IPM phase; however, there was a 20% increase from Aug to Oct 2012 (Fig. 1). The increase in trap catch during the months of Jun, Jul, and Aug 2012 observed in Fig. 1 was a result of increased trap catches from participants A and F (Fig. 2). Total trap catches from all participants (excluding participants who did not comply with basic sanitation practices) between the winter months of the Pre-IPM intervention phase (Oct to Dec 2011) and the IPM-education phase (Oct to Dec 2012) were different ($F = 5.88$; df = 1,87; $P = 0.017$) with mean cockroach counts of 225.3 ± 36.4 and 98.7 ± 37.3 for the Pre-IPM and IPM-education phases, respectively.

For the duration of the entire study period, monthly trap catch from each participants' home was different ($F = 5.57$; df = 1,5; $P = 0.0001$). The highest trap catch was recorded in Dec 2012, Dec 2011, Dec 2011, Aug 2012, Dec 2012, and Aug 2012 for participants A, B, C, D, E, and F, respectively. The lowest trap catch occurred in Mar 2012, Sep 2012, Jul 2013, Oct 2012, Sep 2013, and Mar 2014 for participants A, B, C, D, E, and F respectively (Fig. 2). Each month, the mean number of German cockroaches caught per trap was different ($F = 38.91$; df = 1,26; $P < 0.0001$) among the participants (Fig. 2).

During each of the 3 phases (Pre-IPM, IPM-education, and IPM-education plus bait treatment), total trap catch for individual participants

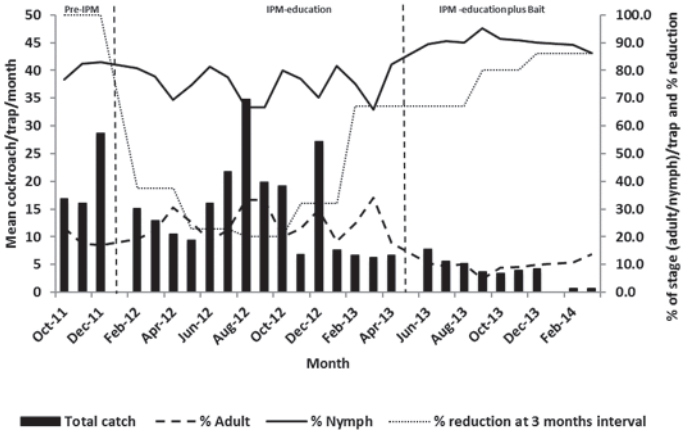


Fig. 1. Population fluctuations of German cockroaches from Oct 2011 to Mar 2014 in 6 manufactured homes in rural North Carolina during the Pre-IPM, IPM-education, and IPM-education plus bait intervention phases.

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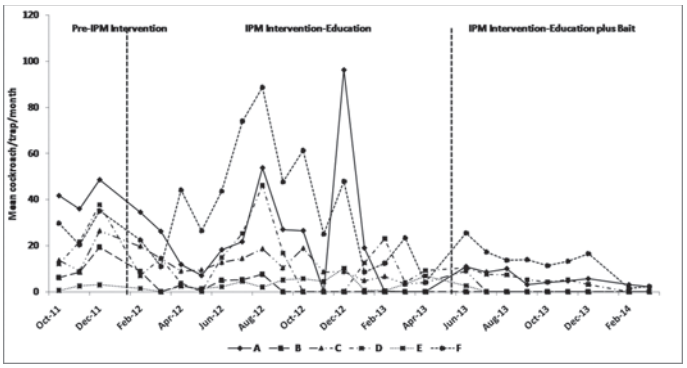


Fig. 2. Trend of monthly mean cockroach trap catches per participant over the sampling period (Oct 2011 to Mar 2014) during the Pre-IPM, IPM-education, and IPM-education plus bait intervention phases.

indicated that the number of cockroaches caught per participant was different (P = 6.00; df = 1,26; P < 0.0001). The highest trap catch during the Pre-IPM intervention months was obtained from participant A but decreased by 51.7% during the IPM-education phase (Fig. 3). Most participants experienced a decrease (64.1, 35.1, and 10.4 % for participants B, D, and C, respectively) in the number of cockroaches caught after IPM-education (Fig. 3). However, the number of cockroaches caught after IPM-education increased for participants E and F (Fig. 3). During the IPM-education plus bait intervention phase, cockroach population levels decreased in all participants' homes (Figs. 2 and 3). At 3 mo intervals during the entire study, Pre-IPM intervention (Oct to Dec 2011), IPM-education (Feb to Apr 2012), and IPM-education plus bait treatment (Jun to Aug 2013) total trap catch from all participants showed a decrease over time when residents were educated about good sanitation practices and a further decrease when education was combined with the use of insecticidal bait (Fig. 3).

Combing all trap catches (adults plus nymphs) between sticky and jar traps showed that Victor Roach® pheromone sticky traps captured significantly (F = 30.87; df =1, 5; P < 0.0001) more cockroaches per trap (19.2 ± 1.9) than the jar traps (7.2 ± 1.1), accounting for 73% of the total number of cockroaches captured by sticky traps compared with 27% by the baited jar trap. In addition, the number of nymphs and adults captured by either jar or sticky trap was different (F = 40.44; df = 1,3; P < 0.0001) between trap type. Victor Roach® pheromone sticky traps captured more nymphs (31.9 ± 3.2) than adults (6.5 ± 0.9) and more cockroaches than the jar traps (nymphs 6.0 ±1.3 or adults 8.5 ± 1.8). Trap catches from all participants for each of the 5 locations when combined were different (F = 29.3; df =1,4; P < 0.0001). German cockroach populations showed a highly uneven dispersion among the 5 locations with the highest trap catch around the refrigerator area (12.2 ± 0.9), followed by the area below the kitchen cabinets (8.4 ± 0.7), above the kitchen cabinets (6.0 ± 0.5), the sink area (5.7 ± 0.5), and the lowest catch around the stove area (3.6 ± 0.3). This distribution indicates that 10% of cockroaches trapped were from stove areas, 16% from sink areas, 17% from above cabinets, 23% from below cabinets, and 34% from the refrigerator areas. However, Fig. 4 indicates that cockroach distribution among 4 locations in individual homes was different, with the highest trap catch being around the refrigerator area for participant B and in the stove area for participant A.

Discussion

The basic starting point for implementing an effective IPM program for household pests should include an understanding of the attitudes and knowledge of residential occupants towards the insect pests in their homes (Wood et al. 1981). In a previous study, we surveyed residents in 3 rural counties in North Carolina on their pest control practices, and found that 93% of the respondents were unfamiliar with the strategy of IPM, and a majority relied mainly on the use of pesticides (Dingha et al. 2013). The 2013 study suggested the need to educate residents on the importance of German cockroaches and the use of IPM strategies for their control. Our results show that during the 3 phases (Pre-IPM intervention, IPM-education intervention, and IPM-education plus bait intervention), the population levels of the German cockroach fluctuated considerably over time (Fig. 1). Although the Pre-IPM German cockroach population levels were high, these were reduced by 38% within 3 mo (Feb to Apr 2012) after implementing the IPM-education (Fig. 1).

The results also show that this decrease only lasted for a few months before increasing again 5 mo later (Aug to Oct 2012), before declining later (Fig. 1). However, this trend was different for individual participants; for example, the mean cockroach catch during the IPM-education phase was higher than during the Pre-IPM phase for participants E and F while it was reduced for the other participants (Fig. 3). After several months of IPM-education, participants E and F still had food left open in their kitchen cabinets and dirty dishes in the sink and did not store food properly, thus creating more favorable conditions for German cockroaches and a scenario for possible re-infestation. This finding demonstrates that an individual's attitude toward learning, comprehension, and application of knowledge obtained can be a major contributing factor for cockroach control. It further suggests that success in the implementing of an educational IPM program largely

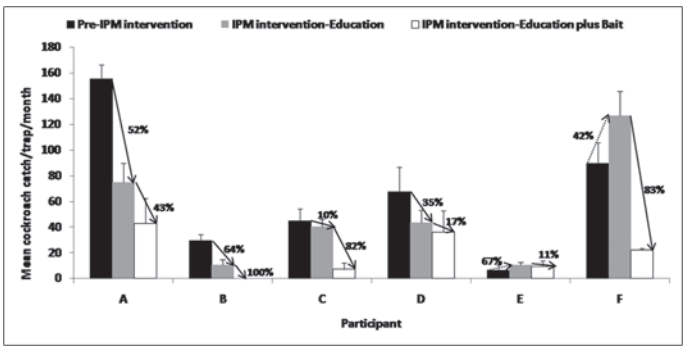


Fig. 3. Total population levels and decrease (%) of German cockroach populations from all participants during the Pre-IPM, IPM-education, and IPM-education plus bait intervention phases for 6 manufactured homes in rural North Carolina.

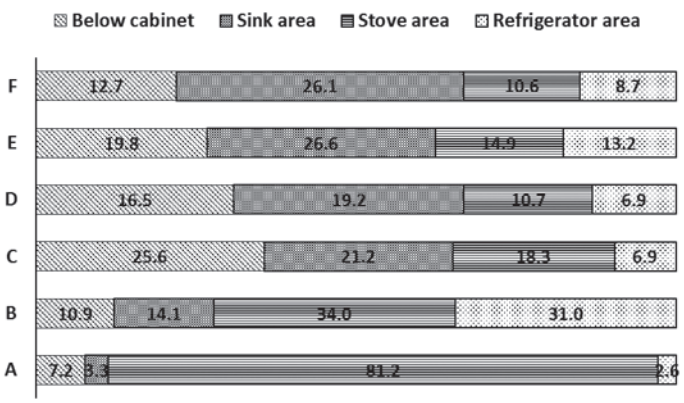


Fig. 4. Distribution of German cockroaches from trap catches at various locations within homes of individual participants.

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depends on the willingness of participants to apply the necessary measures, which may sometimes be as simple as reducing the presence of food, water, and harborage.

A significant positive correlation exists between cockroach population levels and poor sanitation (Schal 1988), probably because cockroaches can actually avoid making contact with insecticide dust or spray or feeding on insecticide bait (Wood et al. 1981, Lee & Lee 2000). In the course of our study, most residents significantly improved their sanitation habits and food handling practices after attending the IPM workshop, receiving verbal guidance during weekly visits, and allowing thorough home inspections. As residents became accustomed to good sanitation and preventive practices, our results indicate declining German cockroach population levels after several months into the IPM education. Similarly, studies at University of Florida housing reported a significant improvement in pest population levels after IPM education (Campbell et al. 1999; Juneau et al. 2011). These findings imply that in due course, education of residents can result in reduced cockroach allergens because high cockroach population densities are correlated with high allergen levels (Wang et al. 2008).

Our results indicate that it takes time for most residents to comply with sanitation practices for German cockroach management. Continuing education is necessary for changing residents' attitudes about the presence of arthropods and implementing an urban pest management program (Byrne et al. 1984). In addition, it might take several years to reduce the pest population depending on the number and kinds of pests infesting residential homes or public housing (Greene & Breisch 2002). Unfortunately, education of residents is usually not a part of the contract set by the pest management contractors of most residential properties. Pest management professionals often feel frustrated by the lack of cooperation from the residents. Lack of proper maintenance of the residence, e.g., poor sanitation and presence of unwashed dishes and clutter in many public housing units, contributes to the cockroach infestation and control failure.

One of the goals of IPM is to reduce the use of insecticides with high toxicity in favor of using low-risk products. In this study, we used Combat® Source Kill Max^{R1} small roach child-resistant bait stations following laboratory testing (Appel et al. unpublished), which indicated it was one of the most efficient control products currently on the market. It has been shown that when integrated with insecticide, sanitation has a significant impact on its effectiveness; for instance, in homes with good sanitation, insecticides were more effective, and those with poor sanitation reduced the efficacy of an otherwise effective insecticide (Schal 1988). Our results indicate that further decrease in German cockroach populations was achieved when insecticidal baits were used in conjunction with education (IPM-education plus bait), and this effect was accompanied by improved sanitation practices when compared with those during the Pre-IPM phase. For instance, within a 3 mo interval after introduction of IPM-education plus bait, the population level was reduced by 68% and 3 mo later by 80% when compared with the initial trap catch during the Pre-IPM intervention phase (Fig. 1). Seven months after application of insecticidal bait plus education treatments, 50% of the participants had 100% trap catch reduction (Fig. 2).

Time of the year appeared to influence cockroach infestation. Trap catches were higher during the warmer months (Jun to Oct 2012) compared with the colder months (Jan to Apr 2013; Fig. 1). In a similar study monitoring German cockroach population levels in low-income apartments for a 12 mo period, an increase in cockroach populations during the warmer months was reported (Koehler et al. 1987). These findings are likely to be related to the effect of higher ambient temperatures and humidity resulting in a more rapid reproduction rate. From our study, another important factor that could have contributed to the high numbers during the warmer months is noncompliance on the part of some participants to keep up with good sanitation and preventive practices, thus leading to high infestations in these homes. Even though colder temperatures can contribute to reducing German cockroach population levels in residential homes, our results indicate that when participants were educated during the winter months of Oct to Dec 2012 (IPM-education intervention), there was a decreased trap catch compared with the catch during the winter months of the Pre-IPM intervention (Oct to Dec 2011).

Placing sticky traps in cockroach-infested areas has been a standard method for monitoring cockroach populations, spatial distribution, and effectiveness of German cockroach management programs (Owens & Bennett 1983). Our results show that sticky traps caught more nymphs than jar traps. This could be because adult cockroaches were able to pull away from sticky traps due to their size and maybe the stickiness of the adhesive for these traps was not enough to hold the adults in place, or simply be an indication of the preponderance of nymphs relative to adults in the homes. Another scenario may be that sticky traps reflect the actual age-class distribution of the population. Jar traps present a hurdle to nymphal capture because from observation, the glass surface is more difficult for them to climb than for adults. This would be a bias in the estimation of cockroach populations that would favor adult census.

Trap catches were highest around the refrigerator areas, and similar results were reported from trap catches in infested apartment kitchens in Alabama and Indiana (Appel 1998; Appel & Reid 1992). However, cockroach distribution in each residential home was different. For participants A, E, and F, the sink area had the highest trap catch, whereas for participant C, it was the area below the cabinet, and for participant B, the stove area. Factors such as warmth around the refrigerator and stove area may be an attraction for cockroaches. On the other hand, the presence of food sources in cabinets and sinks may be more attractive to cockroaches. This difference shows that the distribution of cockroach populations in the kitchen is influenced by the availability of food, shelter, and warmth.

Although traps alone were not effective in controlling cockroach populations, they were able to suppress German cockroaches; a case in point is the capture with sticky traps, which accounted for 73% of cockroaches captured during the entire study period. Sticky traps are safe, nontoxic, and easy to use. They supplement the visual inspection method and provide an additional tool for monitoring and detection (Brenner et al. 2003).

In conclusion, in the present study, we were able to reduce German cockroach populations in a way that minimized exposure of residents to pests and pesticides through the use of IPM strategies that reinforced residents' education on the importance and control of the German cockroach. Emphasizing the benefits of participation in the IPM program made residents more willing to participate. Our results strongly suggest that when residents comply with the information learned and increase the level of sanitation in their homes, sustainable reduction of German cockroach infestation can be achieved. For successful implementation of IPM, we recommend education of residents and property managers on the tenets of IPM and the important role this approach plays in preventing cockroach infestations.

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