

Residents Attitudes and Home Sanitation Predict Presence of German Cockroaches (Blattodea: Ectobiidae) in Apartments for Low-Income Senior Residents

Changlu Wang,^{1,3} Evan Bischoff,^{1,2} Amanda L. Eiden,¹ Chen Zha,¹ Richard Cooper,¹ and Judith M. Graber^{1,2}

¹Department of Entomology, Rutgers University, New Brunswick, NJ 08901, ²Department of Epidemiology, Rutgers University, Piscataway, NJ 08854, and ³Corresponding author, e-mail: changluw@rutgers.edu

Subject Editor: Arthur Appel

Received 18 April 2018; Editorial decision 13 September 2018

Abstract

The German cockroach, *Blattella germanica* (L.), is a common pest found in apartment buildings. Prevalence of cockroach infestations is affected by both environmental conditions and building occupant behavior, but their relationships are not well studied. The objective of this study was to analyze the presence of German cockroaches in relation to environmental conditions, resident demographics, and residents' tolerance of cockroaches. We conducted resident interviews, placed sticky traps to detect the presence of German cockroaches, and assessed apartment conditions. A total of 388 apartments from seven low-income apartment buildings, occupied by senior citizens in New Jersey, United States, were included. Among the 344 apartments where trap count data were obtained, 30% had German cockroaches. Among interviewed residents whose apartments had existing cockroach infestations, 36% were unaware of the presence of cockroaches. The odds of having cockroaches in apartments with a 'poor' sanitation rating in kitchens and bathrooms was 2.7 times greater than that in apartments with better sanitation conditions. Residents' tolerance to cockroaches is significantly associated with presence of cockroaches and cockroach population size. The median cockroach count when residents were bothered by cockroaches was ≥ 3 , based on deployment of 4 sticky traps per apartment, over a 2-wk period. Assessing and reducing cockroach tolerance thresholds and improving housekeeping through resident education and assistance from community and housing management should be incorporated in future cockroach management programs in order to reduce high cockroach infestation rates found in similar communities.

Key words: *Blattella germanica*, tolerance, sanitation, low-income housing

The German cockroach, *Blattella germanica* (L.), is distributed worldwide and is the most common and troublesome cockroach species in apartment buildings in the United States (Bennett et al. 2010). German cockroaches contaminate food, produce allergens that lead to sensitivity, increase asthma morbidity, and cause economic loss to residents as a result of pest control efforts or loss of contaminated food (Bonney et al. 2008). Despite the well-documented human health and economic impacts of cockroach infestations, some residents tolerate low, moderate, or even high levels of cockroach activity in their apartments (Wood et al. 1981). A survey of 258 apartments occupied by families revealed 28% of homes had German cockroaches (Zha et al. 2018). The average trap count per apartment after 1-d placement was 40 cockroaches. As many as 3,657 cockroaches were caught in six sticky traps placed overnight in one occupied apartment (Wang and Bennett 2009). In contrast, some people will take immediate action when even one cockroach is sighted.

Wood et al. (1981) surveyed residents about their tolerance to cockroaches and found 53% of the residents did not consider presence of two cockroaches as a problem. As the threshold increased, the percentage of residents that tolerated them as a problem decreased. Similarly, Zungoli and Robinson (1984) found 45% of the residents would tolerate no more than two cockroaches seen within a 24-h period and tolerance to cockroaches varied between communities. There are no studies on the relationship between cockroach population level and resident sighting or between levels of tolerance and presence or cockroach counts based on monitors.

Sanitation conditions in the home are strongly correlated with the presence of cockroaches in apartments. Although Lee and Lee (2000) did not find a relationship between sanitation and cockroach population levels, most published studies show an increase in cockroach populations with decreasing sanitation (Schal 1988,

Shahraki et al. 2010, Shahraki 2013). An unsanitary environment facilitates cockroach infestations as the necessary food, water, and harborage resources are more abundant and readily accessible compared to a clean environment. Improved sanitation also helps increase the efficacy of insecticide treatments (Schal 1988, Noureldin and Farrag 2008, Dingha et al. 2016). Investigating the environmental conditions in communities where cockroach infestation rates are high, in conjunction with residents' tolerance of cockroach presence, could help identify gaps in cockroach management programs.

The objectives of this study were to analyze the prevalence of German cockroach infestations in relation to environmental conditions, resident demographics, and residents' tolerance to cockroaches in low-income communities for senior and disabled residents using a combination of resident interview, visual observation of living conditions, and placement of sticky traps to quantify infestation levels. The study provides important information on cockroach occurrence patterns in these communities and supports for incorporating educational efforts to improve the effectiveness of the current cockroach management programs.

Experimental Methods

Study Sites and Buildings

Seven apartment buildings housing senior and disabled residents from two cities, Paterson and Irvington, in northern New Jersey, United States were selected for this study. They are managed by the housing authorities in the respective cities. Eligible residents were those living in any of the seven multi-dwelling housing complexes at the time of the study. The housing authority staff for each of the apartment buildings distributed notices to residents in each apartment so occupants would know the time of the interviews and that their apartments would be inspected for cockroaches. On the days of interviews, each apartment was visited at least once to see if the resident was home and would like to participate. There were 933 apartments eligible for the study, with 503 in city of Paterson and 430 in city of Irvington. One adult occupant per apartment completed the interviewer-administered survey. The final study population was 388 residents interviewed; 338 from Paterson and 50 from Irvington. Traps were placed in each participant apartment. Among the apartments, 90% were studio or one-bedroom apartments, 10% were two-bedroom apartments. All residents were low-income senior citizens (≥ 62 yr old) or disabled, 94% were African American or Hispanic. Low-income is defined by U.S. Department of Housing and Urban Development as income below 50% of the median income for the county or metropolitan area where the resident

lives. Institutional Review Board approval from Rutgers University (Protocol #: E17-482) was obtained prior to initiating the study.

Study Design

In this cross-sectional study, a verbal questionnaire was administered to the residents by door-to-door visits during March and April 2017 (Table 1). Gender and ethnicity of the apartment occupants was recorded. Each apartment was visited by one of two teams. Each team consisted of two investigators from Rutgers University. One investigator conducted the interview while the other inspected the cleanliness and clutter in both the kitchen and bathroom. A Spanish-speaking investigator administered the survey to participants who were Spanish-speaking. Written informed consent was obtained and signed by the residents at the time of the interviews in English or Spanish. The sanitation level was rated on scale of 1–3:

1. Good: No dirt or food residues visible on floor, in sink, and on kitchen counter and stove; floor appeared clean.
2. Average: Some food residue, grease visible; floor appeared somewhat dirty.
3. Poor: The stove, kitchen counter and sink, and floor appeared very dirty; presence of abundant food residue, grease, garbage, or leftover food.

The clutter level was rated on scale of 1–3 (corresponding to the scale of 1–3 for kitchen defined by International OCD Foundation (http://www.hoardingconnectioncc.org/Hoarding_cir.pdf). Condition of the kitchen cabinets was added as a secondary criterion. The higher rating was given when the cabinets condition did not match with conditions of the open areas:

1. Little: Both counter and floor have few household items; most cabinets are less than half full.
2. Average: Some household items, but not overly crowded.
3. Cluttered: Many items present on the kitchen and bathroom floors and kitchen counter; all cabinets are very full.

Four Trapper monitor & insect traps (1/3 of the whole piece) (Bell Laboratories Inc., Madison, WI) were installed in each apartment while conducting interviews. The location of each trap placement was similar in each apartment: 1) under the kitchen sink, 2) next to the stove, 3) next to the refrigerator, and 4) beside the toilet in the bathroom.

Thirteen to 15 d following trap placement, the traps were examined for presence of cockroaches and the number of cockroaches was counted. All trap counts were adjusted to 14-d counts during analysis. In 71 apartments (18%), some or all of the traps were missing. We excluded 37 apartments that had #2 and/or #3 trap missing

Table 1. Questionnaire administered by investigator to residents about cockroach infestations

1. How many years have you lived in this apartment?
2. Do you see cockroaches in your apartment? Yes ___; No ___
 ---If YES: How often do you see them? ___ How long they have been present? ___
 Does seeing cockroaches bother you? ___
 When do cockroaches begin to be bother you? Cockroaches appear daily ___, once a week ___, monthly ___ never ___; or number of cockroaches 1 ___, 5 ___, 10 ___
 ---If NO: When was the last time you experienced a cockroach infestation? ___
 When do cockroaches begin to be bother you? Cockroaches appear daily ___, once a week ___, monthly ___ never ___; or number of cockroaches 1 ___, 5 ___, 10 ___
3. What you have done to control cockroaches in the last 6 mo? spray ___; dust ___; bait ___; Other _____
4. What products you have purchased for cockroach control in the last 6 mo? _____

Those residents who were at home were included.

in data analysis because these two locations were most important for detecting cockroaches. For apartments with #1 and/or #4 trap missing, an adjusted total trap count was calculated based on relative abundance of cockroaches at #1 to #4 locations, which was 13, 30, 51, and 6% based upon the apartments with no missing traps. If trap #1 was missing and the total trap count at #2 to #4 was 10, the estimated trap #1 count would be $10 \times 13/(100-13) = 1.5$ and the total count for the apartment would be adjusted to 11.5. Similarly, if traps #1 and #4 were missing and total trap count at #2 and #3 was 10, the estimated total count for traps #1 and #4 would be $10 \times (13 + 6)/(100-13-6) = 2.3$ and total count for the apartment would be adjusted to 12.3. A total of nine apartments had cockroaches and the counts were adjusted. There were 24 apartments with #1 and/or #4 trap missing and no cockroaches were found. These apartments were considered having no cockroaches.

Data Analysis

Chi-square tests were used to assess associations between the presence of cockroaches and the following variables: ethnicity (African American vs. Hispanic), gender, bathroom sanitation and clutter, kitchen sanitation and clutter, and tolerance to cockroaches. Chi-square tests also were used to examine associations between tolerance level and cockroach sighting. Logistic regression was used to assess the associations between cockroach presence and apartment sanitation rating and between cockroach presence and years of residence and calculate the odds ratios. A multiple regression model was not used for predicting cockroach presence due to association between key variables (e.g., kitchen sanitation vs. ethnicity, kitchen sanitation vs. clutter). The Kruskal-Wallis test was used to compare trap counts between apartments where residents sighted cockroaches and those did not sight cockroaches based on interview, and between those are bothered when seeing one cockroach and those are bothered when seeing five cockroaches. All statistical analyses were conducted using SAS software (version 9.3; SAS Institute, Cary, NC) (SAS Institute 2011).

Results

Characteristics of German Cockroach Infestations in Relation to Occupants and Apartment Conditions

Descriptive characteristics for the study sample are shown in Table 2. Among the study respondents, almost all (98%) lived in single occupancy apartments.

Of 3,342 cockroaches found in traps collected from 112 infested apartments, all were German cockroach, *B. germanica*. Small nymphs, large nymphs, male adults, and female adults represented for 70, 17, 8, and 5% of the total catch. In the 344 apartments where trap count data were available and none of the traps at #2 and #3 locations were missing, 30% had cockroaches. Distribution of cockroach trap counts is shown in Fig. 1.

Among respondents in apartments with confirmed cockroach activity in traps, 36% indicated that they were unaware of the presence of cockroaches. Lack of awareness was related with cockroach population size: 52% were unaware of the presence of cockroaches while the trap counts were ≤ 5 , 23% were unaware cockroaches were present when trap counts were >5 and ≤ 10 , and 4% were unaware cockroaches were present while trap counts were >10 . Conversely, among those saying cockroaches were present, 34% did not have cockroaches based on trap counts. We considered trap count data as a more valid measurement of cockroach activity than resident observation, so we used trap count data in the analysis of association between presence of cockroaches and resident characteristics and apartment conditions.

The presence of cockroaches was not significantly associated with ethnicity, gender (Table 2), or years of residence ($\chi^2 = 0.20$; $P = 0.65$). The mean (\pm SEM) length of residence was 7.7 ± 0.4 yr.

Both kitchen and bathroom sanitation ratings were positively and significantly associated with presence of cockroaches. Among the surveyed apartments, 10 and 7% of the kitchens and bathrooms were rated 'poor', respectively. The odds of having cockroaches in apartments with 'poor' sanitation rating in kitchens is 2.7 times (95% CI: 1.3–5.8) greater than that in apartments with a 'good' or 'average' rating. Similarly, the odds of having cockroaches in apartments with 'poor' bathroom sanitation rating is 2.7 times (95% CI: 1.2–6.4) greater than that in apartments with a 'good' or 'average' rating. However, clutter level in the kitchen or bathroom were not related to presence of cockroaches ($P > 0.05$).

Residents' Attitudes Toward Cockroach Infestations

Among the 314 residents who answered the question 'When do cockroaches bother you?', 15% said they were never bothered by cockroaches and the remainder said would be bothered when seeing cockroaches weekly to monthly. The distribution of the tolerance levels (seeing cockroaches weekly to monthly) was not related to cockroach presence based on interview (Table 3). The reasons for answering 'never' to the question were: 1) never encountered

Table 2. Descriptive characteristics of survey respondents and presence of German cockroaches based on trap catch

Characteristics	Value	<i>n</i> ^a	% apartments infested	Chi-square test
Ethnicity	African American	169	30	$\chi^2 = 0.01$; $P = 0.92$
	Hispanic	155	30	
Gender	Female only	200	27	$\chi^2 = 2.2$; $P = 0.13$
	Male only	139	35	
Kitchen sanitation	Good to average	310	28	$\chi^2 = 7.4$; $P = 0.01$
	Poor	31	52	
Kitchen clutter	Little to average	314	31	$\chi^2 = 0.9$; $P = 0.35$
	Cluttered	27	22	
Bathroom sanitation	Good to average	318	29	$\chi^2 = 5.6$; $P = 0.02$
	Poor	23	52	
Bathroom clutter	Little to average	322	26	$\chi^2 = 0.1$; $P = 0.70$
	Cluttered	19	30	

^aTotal sample size for each investigated characteristic varied due to missing answers.

cockroaches in their homes, 2) used to live in the south where cockroaches were very common, and 3) they would just kill them.

Residents' tolerance of cockroaches was significantly associated with presence of cockroaches based on interview or trap count data (Table 4). Cockroach trap counts were significantly lower among people who said they would be bothered by seeing one cockroach compared with those who would be bothered by seeing five cockroaches (2.8 ± 0.6 vs. 4.7 ± 1.5 cockroaches based on trap count; [$\chi^2 = 8.1$; $P = 0.004$]).

The frequency of cockroach sighting and the corresponding actual cockroach population size is shown in Table 5. The median trap count when people are bothered by seeing cockroaches ranged between 3 and 19 cockroaches. In this study, 54% of the infested

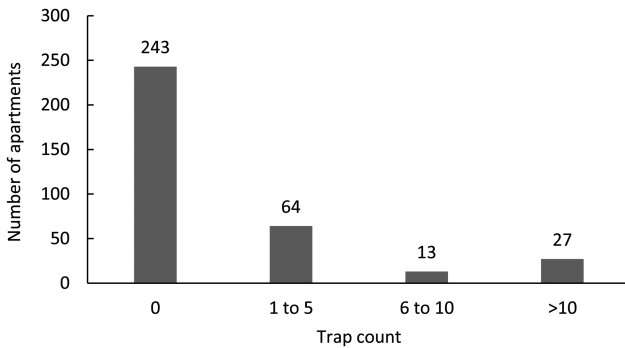


Fig. 1. Distribution of cockroach trap counts among apartments with trap count data. Four traps were placed in each apartment and they were retrieved and inspected after 2 wk. Those apartments with #2 and/or #3 trap missing were excluded.

apartments had cockroach counts <3 . Therefore, a majority of tenants who have cockroaches would not be bothered by the presence of cockroaches.

Residents' Self-Implemented Methods to Reduce Cockroach Numbers

Among 384 interviewed residents, 74% implemented methods themselves to control cockroaches. The methods used were: spray (55%), keeping their apartment clean (24%), trapping (9%), insecticide bait (6%), insecticide dust (5%), and an electronic device (1%). Among 188 residents who could recall the types of products purchased for cockroach control, 72 and 8% bought sprays and insecticide dusts, respectively. Other types of products represented less than 5% of those purchased. Among the 118 respondents who answered the question 'Can cockroaches be eliminated?', 66% answered 'yes', 19% 'No', and 14% were 'not sure'.

Discussion and Conclusions

This study found that presence of cockroaches was associated with higher tolerance levels and poor sanitary conditions. Also, cockroach counts were associated with tolerance levels. Additionally, in our study, the majority of infestations had low numbers of cockroaches and 36% of the residents who had cockroaches found in traps in their apartments were unaware of the presence of cockroaches. These findings suggest that proactive inspection and monitoring for the presence of cockroaches is necessary for sustainable and better cockroach management, as many infestations, particularly low-level ones may go undetected. For detecting low-level cockroach infestations, we found that a 2-wk or longer placement period is effective.

Table 3. Relationship between tolerance (how often seeing cockroaches would bother you?) and presence of cockroaches based on interview

Cockroaches present in home?	<i>n</i> (%)	Frequency of seeing cockroaches before residents indicated they would be bothered				Chi-square test
		Daily	Once a week	Once a month	Never	
No	212 (68%)	27 (13%)	30 (14%)	137 (65%)	18 (8%)	$\chi^2 = 1.07$; $P = 0.78$
Yes	102 (32%)	15 (15%)	16 (16%)	60 (59%)	11 (11%)	

Table 4. Relationship between tolerance (seeing how many cockroaches would bother you?) and presence of cockroaches

Cockroaches present in home?	Survey method	Value	<i>n</i>	Number of cockroaches seen before residents indicated they would be bothered		Chi-square test
				One	Five	
Interview	No		228	171 (75%)	57 (25%)	$\chi^2 = 4.2$; $P = 0.04$
	Yes		109	70 (64%)	39 (36%)	
Trap count	No		208	159 (76%)	49 (24%)	$\chi^2 = 7.6$; $P = 0.01$
	Yes		89	54 (61%)	35 (39%)	

Table 5. Relationship between cockroach sighting frequency (how often seeing cockroaches?) and cockroach trap counts

How often seeing cockroaches?	<i>N</i>	Trap count at 14 d (Mean \pm SEM) ^a	Median (min, max)
Every 1–3 d	29	21 \pm 4a	19 (1, 79)
Once a week	17	13 \pm 4b	3 (1, 59)
Once a month	19	9 \pm 2b	7 (1, 35)

Those apartments with trap count ≥ 1 and residents seeing cockroaches were included.

^aMeans followed by different letters are significantly different (Kruskal-Wallis test; $P < 0.05$).

Additionally, educating residents on the importance of cockroach infestations may be an important strategy to reduce cockroach infestations and may aid in increasing resident reporting of cockroach activity in apartments. The high rate (30%) of infestation also indicates existing pest control service and self-implemented treatment were ineffective.

This study was designed to sample a relatively homogeneous population (i.e., elderly, mostly single, low-income, African American and Hispanic dwellers). Even though our study population is relatively homogenous, we saw significant variations in their tolerance to cockroaches. There are many possible factors that might contribute to this variation including post-exposure history, presence of respiratory disease, sensitivity to cockroach allergens, and/or lack of success with previous cockroach control attempts. We found a positive association between tolerance and presence of cockroach infestations. People who were bothered by only one cockroach had lower trap counts than those bothered by five cockroaches. Possible explanations for residents not bothered, include that these residents may have: 1) an acquired tolerance to the presence of cockroaches, 2) low expectations of building management responsiveness to requests for pest control treatment, and 3) privacy concerns.

Our findings are consistent with previous literature, that the presence of cockroach infestations is associated with apartment sanitation conditions (Wood et al. 1981, Schal 1988, Shahraki et al. 2010). Only 10 and 7% of the apartments had poor sanitation conditions in kitchens and bathrooms, respectively. This information can be used for estimating the benefit of education and good housekeeping in cockroach management. Investing extra effort in these apartments will likely maximize the control effect as these apartments may suffer chronic infestations and become sources of new infestations in multi-unit dwellings. Previous studies on the effect of education on sanitation had mixed results (Wang and Bennett 2009, Dingha et al. 2016, Zha et al. 2018). Since knowledge is insufficient for behavioral change, and this is a low resource population, providing regular cleaning services to apartments with ongoing sanitation issues is an option that also should be considered.

Only 66% of the surveyed residents were confident that German cockroaches can be eliminated. This may have to do with the high cockroach infestation rates and frequent re-infestations in apartment buildings. Cockroach baits have existed in the U.S. market for over 25 yr and are proven to be very effective for eliminating cockroach infestations (Appel 1992, Nalyanya et al. 2001, Appel 2003, Wang and Bennett 2006, Wang et al. 2013). However, 55% of the surveyed residents purchased insecticide sprays for control rather than baits in an effort to control cockroaches themselves. As such, there is a great need for educating the public about safer and more effective cockroach control methods. Creative methods may be needed to give these residents access to more effective pest control methods, such as door-to-door delivery of educational materials. Additionally, the professional pest control services currently hired by the low-income communities also need to be improved as plenty of evidence showing adopting IPM with currently available technologies will result in much better cockroach control (Miller and Meek 2004, Wang and Bennett 2009, Zha et al. 2018). Together with other educational effort on residents' attitudes toward cockroaches and housekeeping behavior, better cockroach control, and confidence in elimination could be achieved.

German cockroaches are likely to continue to be a major indoor pest with both nuisance and public health implications (Olmedo et al. 2011, Yuenyongviwat et al. 2013). To reduce the status of cockroaches as a major indoor pest and decrease their health

impact, better educational strategies must be developed to increase the cooperation of residents in cockroach management and increase the quality of professional pest control services in these communities. This study provides quantitative analysis of the obstacles and challenges present in low-income apartments. The tolerance and sanitation data can be used in formulating cockroach management policies and procedures. Further research is needed on the effectiveness of various educational and non-chemical intervention methods to control cockroach populations and the economic and environmental benefit (cost, allergen reduction, insecticide residue reduction). This study should serve as a platform to extend to new levels of better control of cockroach infestations in residential communities.

Acknowledgments

We are grateful to the staff assistance from housing authorities in Irvington and Paterson. We thank Dr. Cara Cuite for assistance in designing the questionnaire. This study was supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, through the Northeastern Integrated Pest Management Center under award number 2014-70006-22484; and the Agriculture Hatch Project 100011133 through the New Jersey Agricultural Experiment Station. This is New Jersey Experiment Station Publication # D-08-08127-09-17.

References Cited

- Appel, A. G. 1992. Performance of gel and paste bait products for German cockroach (Dictyoptera: Blattellidae) control: laboratory and field studies. *J. Econ. Entomol.* 85: 1176–1183.
- Appel, A. G. 2003. Laboratory and field performance of an indoxacarb bait against German cockroaches (Dictyoptera: Blattellidae). *J. Econ. Entomol.* 96: 863–870.
- Bennett, G. W., J. M. Owens, and R. M. Corrigan. 2010. Truman's scientific guide to pest control operations. Questex Media Group LLC, Cleveland, OH.
- Bonnefoy, X., H. Kampen, and K. Sweeney. 2008. Public health significance of urban pests. World Health Organization, Copenhagen, Denmark.
- Dingha, B. N., J. O'Neal, A. G. Appel, and L. E. Jackai. 2016. Integrated pest management of the German cockroach (Blattodea: Blattellidae) in manufactured homes in rural North Carolina. *Florida Entomol.* 99: 587–592.
- Lee, C., and L. Lee. 2000. Diversity of cockroach species and effect of sanitation on level of cockroach infestation in residential premises. *Trop. Biomed.* 17: 39–43.
- Miller, D. M., and F. Meek. 2004. Cost and efficacy comparison of integrated pest management strategies with monthly spray insecticide applications for German cockroach (Dictyoptera: Blattellidae) control in public housing. *J. Econ. Entomol.* 97: 559–569.
- Nalyanya, G., D. Liang, R. J. Kopanic, Jr, and C. Schal. 2001. Attractiveness of insecticide baits for cockroach control (Dictyoptera: Blattellidae): laboratory and field studies. *J. Econ. Entomol.* 94: 686–693.
- Noureldin, E. M., and H. A. Farrag. 2008. The role of sanitation in the control of German cockroach (*Blattella germanica* L.). *Biosci., Biotech. Res. Asia.* 5: 525–536.
- Olmedo, O., I. F. Goldstein, L. Acosta, A. Divjan, A. G. Rundle, G. L. Chew, R. B. Mellins, L. Hoepner, H. Andrews, S. Lopez-Pintado, et al. 2011. Neighborhood differences in exposure and sensitization to cockroach, mouse, dust mite, cat, and dog allergens in New York City. *J. Allergy Clin. Immunol.* 128: 284–292.e7.
- SAS Institute. 2011. SAS/STAT user's guide; version 9.3, Cary, North Carolina.
- Schal, C. 1988. Relation among efficacy of insecticides, resistance levels, and sanitation in the control of the German cockroach (Dictyoptera: Blattellidae). *J. Econ. Entomol.* 81: 536–544.
- Shahraki, G. H. 2013. Evaluation of sanitation in an IPM program for cockroach infestation in housing. *J. MacroTrends Health Med.* 1: 58–62.

- Shahraki, G. H., H. M. Noor, J. Rafinejad, M. K. Shahar, and Y. B. Ibrahim. 2010. Efficacy of sanitation and sanitary factors against the German cockroach (*Blattella germanica*) infestation and effectiveness of educational programs on sanitation in Iran. *Asian Biomed.* 4: 803–810.
- Wang, C., and G. W. Bennett. 2006. Comparative study of integrated pest management and baiting for German cockroach management in public housing. *J. Econ. Entomol.* 99: 879–885.
- Wang, C. L., and G. W. Bennett. 2009. Cost and effectiveness of community-wide integrated pest management for German cockroach, cockroach allergen, and insecticide use reduction in low-income housing. *J. Econ. Entomol.* 102: 1614–1623.
- Wang, C., N. Singh, R. Cooper, and C. Scherer. 2013. Baiting for success. *Pest Control Technol.* 41(7): 60–64.
- Wood, F., W. H. Robinson, S. K. Kraft, and P. A. Zungoli. 1981. Survey of attitudes and knowledge of public housing residents toward cockroaches. *Bull. Ent. Soc. Amer.* 27: 9–13.
- Yuenyongviwat, A., D. Koonrangsomboon, and P. Sangsupawanich. 2013. Recent 5-year trends of asthma severity and allergen sensitization among children in southern Thailand. *Asian Pac. J. Allergy Immunol.* 31: 242–246.
- Zha, C., C. Wang, B. Buckley, I. Yang, D. Wang, A. L. Eiden, and R. Cooper. 2018. Pest prevalence and evaluation of community-wide integrated pest management for reducing cockroach infestations and indoor insecticide residues. *J. Econ. Entomol.* 111: 795–802.
- Zungoli, P. A., and W. H. Robinson. 1984. Feasibility of establishing an aesthetic injury level for German cockroach pest management programs. *Environ. Entomol.* 13: 1453–1458.