18

Evaluation of German Cockroach (Orthoptera: Blattellidae) Allergen and Seasonal Variation in Low-Income Housing

J. A. MOLLET, L. D. VAILES,[1] D. B. AVNER,[1] M. S. PERZANOWSKI,[1] L. K. ARRUDA,[1] M. D. CHAPMAN,[1] AND T.A.E. PLATTS-MILLS[1]

Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061

J. Med. Entomol. 34(3): 307–311 (1997)

ABSTRACT Six apartments in a low-income housing project were evaluated for German cockroach, *Blattella germanica* (L.), infestation and concentration of an allergen derived from these cockroaches (*Bla g* II). Kitchen and living room samples were collected monthly for 1 yr. In addition, airborne sampling was carried out in 5 kitchens. The kitchen had the highest allergen concentration in 65% of visits and the highest number of cockroaches trapped in 69% of visits. In the kitchen, the highest cockroach levels were seen in June, whereas the values for *Bla g* II peaked in August. In keeping with this, the closest correlation was between *Bla g* II (μg/g dust) and the number of cockroaches found 2 mo earlier. Airborne samples were assayed for 2 separate allergens, *Bla g* II and *Bla g* I. No allergen was detectable in the absence of disturbance. By contrast, during disturbance with a vacuum cleaner both *Bla g* II and *Bla g* I were detectable in the air of each apartment. Results suggest that immunochemical assay of a major allergen in dust samples from the kitchen floor may be used to monitor exposure to German cockroaches, also that cockroach levels may be used as an indicator or predictor of allergen in dust.

KEY WORDS *Blattella germainca*, German cockroach, allergen, seasonality

AS THE PREVALENCE and morbidity of asthma continues to increase in the United States, investigators have sought to identify and define risk factors responsible for asthma attacks (Platts-Mills and Chapman 1987). Attention has focused recently on the role of indoor allergens, principally dust mites, cockroaches, and animal danders, as causes of asthma (Sly 1988, CDC 1990, Weiss and Wagener 1990). The increase in asthma in the United States is most marked among persons in lower socioeconomic groups who live in urban or inner city areas, and is prevalent in African-American and Hispanic populations (Sly 1988, CDC 1990, Weiss and Wagener 1990, Call et al. 1992, Weiss et al. 1992, Gelber et al. 1993, Pope et al. 1993). Recent studies suggest that sensitization to cockroach allergens is common in urban areas, and is a risk factor for asthma among people who live in cockroach infested houses (Call et al. 1992, Gelber et al. 1993, Arruda et al. 1995).

Most studies on cockroaches as allergen producers have focused on the German cockroach, *Blattella germanica* (L.), the species most prevalent in the home environment. Allergens have been identified in fecal as well as whole body extracts (Lehrer et al. 1991, Musmand et al. 1995). Many allergens have been identified from this insect, but so far only 2 are identified easily from house dust using enzyme-linked immunosorbent assays (ELISA) (Pollart et al. 1991a, b). These are called *Bla g* I and *Bla g* II according to standard procedures for naming allergens (Helm et al. 1988, Wu and Lan 1988, Schou et al. 1990, Stankus et al. 1990, Pollart et al. 1991b).

For the allergen *Bla g* II, a threshold level of 2 units/gm of house dust has been proposed (Gelber et al. 1993). Recently, this has been shown to represent 80 ng allergen per gram of dust (Arruda et al. 1995). Persons predisposed to sensitization would become allergic to cockroaches if exposed to levels higher than this threshold. It would be helpful to those with allergy to cockroaches to know if the allergen is more prevalent during a certain time of the year, and how cockroach levels in the home affect the presence of allergen.

Because respiratory allergens must be inhaled, their airborne presence is also important. *Bla g* I and *Bla g* II allergens were found in air samples taken directly over living colonies of German cockroaches (Helm et al. 1993), but little work has been done testing for cockroach allergen in residences.

Researchers in the Department of Entomology at Virginia Tech have worked extensively with the managers and residents of an apartment complex administered by the Roanoke Redevelopment and Housing Authority in Roanoke, VA, to understand

[1]Division of Allergy and Clinical Immunology, Department of Medicine, University of Virginia, Charlottesville, VA 22908.

Table 1. Mean amount of German cockroach allergens present in the air of apartments before and during disturbance

Apt. no.	Background		Disturbance	
	Bla g I	*Bla* g II	*Bla* g I	*Bla* g II
1	<0.02	<1.0	0.19	13.6
2	<0.02	<1.0	0.50	7.8
3	<0.02	<1.0	0.29	11.6
4	<0.02	<1.0	0.20	3.2
5	<0.03	<1.0	0.27	13.6

Each number represents a 30-m sample with 2 parallel filters before and after 10-m disturbance with filterless vacuum cleaner, mean value for 2 filters. *Bla* g I allergen levels represent mean units allergen per cubic meter of air. *Bla* g II allergen levels represent mean nanograms of allergen cubic meter of air.

and alleviate their cockroach control problems (Robinson et al. 1981; Zungoli and Robinson 1984; Robinson and Zungoli 1985; Thoms and Robinson 1987a, b; Zhai and Robinson 1992). This background knowledge in German cockroach biology and control, as well as access to the apartment complex, made it possible to carry out the current study on the seasonality of cockroach allergen and cockroach numbers.

Materials and Methods

Preliminary sampling of cockroach density was done in 11 apartments. Cockroach density in each apartment was determined using Mr. Sticky (Long Island, NY) sticky traps, a tent-shaped cardboard trap with the floor covered with an adhesive substrate (8.25 by 16.5 cm) (30% synthetic rubber, 50% hydrogenated petroresin, 15% plasticizer, and 5% antioxidant). Cockroaches entering this trap are caught in the substrate. One sticky trap was placed in the kitchen near the refrigerator; it was left out for 24 h and then German cockroaches mired in the substrate were counted. From this presampling, 6 apartments were selected, representing a range of cockroach densities, for a year-long study monitoring both allergen and cockroaches.

The major site of cockroach allergen in a home is known to be the kitchen, with lesser amounts found in the living room and bedrooms (Pollart et al. 1991a, Call et al. 1992). For this study, the kitchen was considered to be the primary site for sampling. The living room was sampled as a secondary site.

To sample for German cockroach allergen in the air, 5 apartments were sampled. Airborne samples were collected from the kitchens of 5 of the 6 apartments. The 1st was sampled in December 1994, as a pilot study, and the other 4 were sampled in January 1995. Two airborne samplers with glass fiber filters (Millipore, Bedford, MA) were supported 0.6 m above the kitchen floor on a retort stand. Air was sampled for 30 min at a flow rate of 18 liters/min (0.54 m^3 total air sampled) through each filter (Luczynska et al. 1990). The experiment was then repeated with disturbance. Dust was disturbed artificially for the first 10 min of the 2nd sampling period by vacuuming with a Shop Vac vacuum cleaner (Shop Vac, Williamsport, PA) from which the filter had been removed. The duplicate glass filters were then eluted overnight at 4°C in 1 ml of 1% bovine serum albumin in phosphate buffered saline. Extracts were obtained by compress-

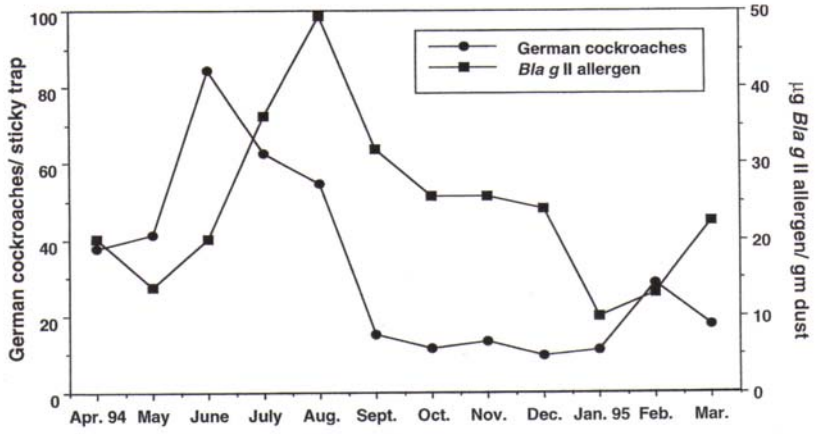

Fig. 1. Mean micrograms of *Bla* g II allergen per gram of house dust and mean number of German cockroaches in kitchens, when sampled monthly.

Table 2. Correlation of German cockroaches and *Bla g* II allergen in kitchens and living rooms

Correlation between monthly avg *Bla g* II and monthly avg cockroaches	Kitchen		Living room	
	r	*P*	*r*	*P*
2 mo later	0.0016	NS	0.13	NS
1 mo later	0.072	NS	0.043	NS
Same month	0.27	0.02*	0.25	0.03*
1 mo previous	0.41	<0.001***	0.22	0.07 NS
2 mo previous	0.52	<0.001***	0.25	0.06 NS
Mean no. total cockroaches	32 ± 5		13 ± 2	
Mean *Bla g* II levels (μg/g dust)	24.6 ± 3.2		17.2 ± 2.8	

Kitchens had more cockroaches collected in 49/71 visits and higher *Bla g* II levels in 46/71 visits. NS, not significant, $P > 0.05$; *, $0.05 > P > 0.01$; ***, $P < 0.001$.

ing the filter in a 3 ml plastic syringe and were assayed by ELISA for *Bla g* I and *Bla g* II (Pollart et al. 1991b).

To sample for dust carrying allergen, an efficient vacuum with a piece of sheeting material (18 by 18 cm^2) inserted between the hose and nozzle was used. The area around the perimeter of the kitchen floor and refrigerator was vacuumed; the dust was placed in a marked plastic bag and refrigerated. The living room perimeter and around any upholstered furniture was also sampled, with dust collected and stored as before. Cockroach populations were evaluated by sticky trap counts in both locations 24 h after dust collection. No pesticides were used during this trial, which eliminated any possible confounding effects of pesticide–allergen interactions.

Dust was sieved through a brass, 50-mesh sieve, and 100 mg was mixed with 2 ml of phosphate-buffered saline containing 0.05% Tween 20 at room temperature for 2 h. Water-soluble proteins containing allergen dissolved into this saline solution with a small amount of detergent. The mixture was centrifuged at 750 × *g* to separate liquid and dust, with the liquid drawn off and frozen until analysis (Call et al. 1992). A 2-site monoclonal antibody-based ELISA was used to detect and measure the *Bla g* II allergen in the extract (Pollart et al. 1991a, b).

Results and Discussion

Air sampling results are found in Table 1. Allergen levels were never more than the lowest detectable amount until the air was disturbed. This is similar to house dust mite (*Dermatophagoides* spp.) allergen, which is also dependent on disturbance to become airborne (de Blay et al. 1991).

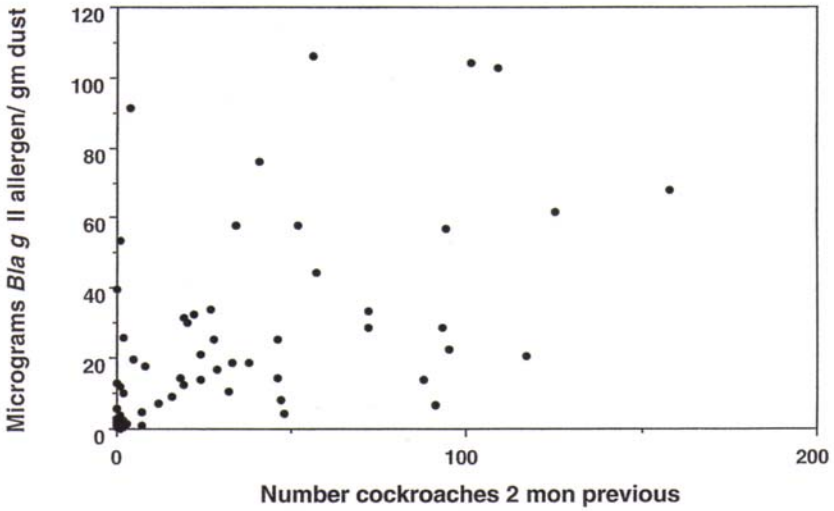

Fig. 2. Correlation comparing micrograms of *Bla g* II allergen per gram of dust with the number of cockroaches in sticky traps 2 mo previous.

The numbers of German cockroaches found in sticky traps and the units of *Bla g* II allergen per gram of dust in the kitchens were averaged for each sampling date (Fig. 1). There is an obvious peak for numbers of cockroaches and allergen, but they do not appear at the same time (June for cockroaches and August for allergen). Regression analysis comparing allergen levels and cockroach numbers show a correlation coefficient of 0.27 ($P = 0.02$).

The buildup of allergen could logically lag behind a peak in cockroach numbers. Feces, cast skins, and dead bodies, as well as living German cockroaches, all have significant amounts of allergen (Lehrer et al. 1991, Menon et al. 1991). This debris, which results from the presence of cockroaches, builds up slowly in a residence infested with these insects.

There is a correlation (Table 2) between allergen levels against cockroach numbers at the same time, 1 or 2 mo previous and 1 or 2 mo earlier. For data collected in kitchens, the best correlation coefficient ($r = 0.52$, $P < 0.001$) is found when the allergen level is compared with cockroach numbers 2 mo previous. Fig. 2 shows allergen levels compared with cockroach numbers 2 mo previous.

Future studies, including more residences, and incorporation of other factors such as cleaning habits and conditions in the residence (carpeted or not, type of heating or cooling systems) will help determine the factors that affect allergen levels.

Acknowledgment

This work was partially funded by National Institutes of Health grants AI 20565 and U01-AI-34607.

References Cited

Arruda, L. K., L. D. Vailes, B. J. Mann, J. Shannon, J. W. Fox, T. S. Vedvick, M. L. Hayden, and M. D. Chapman. 1995. Molecular cloning of a major cockroach (*Blattella germanica*) allergen, *Bla g* 2. J. Biochem. 270: 19563–19568.

de Blay, F., P. W. Heymann, M. D. Chapman, and T.A.E. Platts-Mills. 1991. Airborne dust mite allergens: comparison of group II allergens with group I mite allergen and cat-allergen *Fel d* I. J. Allergy Clin. Immunol. 88: 919–926.

[CDC] Centers for Disease Control. 1990. Asthma: United States, 1980–1987. Morb. Mortal. Wkly. Rep. 39: 493–497.

Call, R. S., T. F. Smith, E. Morris, M. D. Chapman, and T.A.E. Platts-Mills. 1992. Risk factors for asthma in inner city children. J. Pediatr. 121: 862–866.

Gelber, L. E., L. Seltzer, J. K. Bouzoukis, S. M. Pollart, M. D. Chapman, and T.A.E. Platts-Mills. 1993. Sensitization and exposure to indoor allergens (dust mite, cat and cockroach) as risk factors for asthma among patients presenting to hospital. Am. Rev. Respir. Dis. 147: 573–578.

Helm, R. M., E. O. Bandele, M. C. Swanson, A. T. Campbell, and S. R. Wynn. 1988. Identification of a German cockroach-specific allergen by human IgE and rabbit IgG. Int. Arch. Allergy Appl. Immunol. 87: 230.

Helm, R. M., W. Burks, L. W. Williams, D. E. Milne, and R. J. Brenner. 1993. Identification of cockroach aeroallergens from living cultures of German or American cockroaches. Int. Arch. Allergy Immunol. 101: 359–363.

Lehrer, S. B., W. E. Horner, P. Menon, and R. P. Stankus. 1991. Comparison of cockroach allergenic activity in whole body and fecal extracts. J. Allergy Clin. Immunol. 87: 574–580.

Luczynska, C. M., Y. Li, M. D. Chapman, and T.A.E. Platts-Mills. 1990. Airborne concentrations and particle size distribution of allergen derived from domestic cats (*Felis domesticus*). Am. Rev. Respir. Dis. 141: 361–367.

Musmand, J. J., W. E. Horner, M. Lopez, and S. B. Lehrer. 1995. Identification of important allergens in German cockroach extracts by sodium dodecylsulfate-polyacrylamide gel electrophoresis and Western blot analysis. J. Allergy Clin. Immunol. 95: 877–885.

Menon, P., V. Menon, B. Hillman, R. Stankus, and S. B. Lehrer. 1991. Skin test reactivity to whole body and fecal extracts of American (*Periplaneta americana*) and German (*Blattella germanica*) cockroaches in atopic asthmatics. Ann. Allergy 67: 573–577.

Platts-Mills, T.A.E., and M. D. Chapman. 1987. Dust mites: immunology, allergic disease, and environmental control (review). J. Allergy Clin. Immunol. 80: 755–775.

Pollart, S. M., T. F. Smith, E. Morris, L. E. Gelber, T.A.E. Platts-Mills, and M. D. Chapman. 1991a. Environmental exposure to cockroach allergens: analysis with monoclonal antibody-based enzyme immunoassays. J. Allergy Clin. Immunol. 87: 505–510.

Pollart, S. M., L. D. Vailes, D. E. Mullins, M. L. Hayden, T.A.E. Platts-Mills, W. M. Sutherland, and M. D. Chapman. 1991b. Identification, quantitation and purification of cockroach allergens using monoclonal antibodies. J. Allergy Clin. Immonol. 87: 511–521.

Pope, A. M., R. Patterson, and H. Burge [eds.]. 1993. Indoor allergens. Assessing and controlling adverse health effects. National Academy Press, Washington, DC.

Robinson, W. H, and P. A. Zungoli. 1985. Integrated control program for German cockroaches (Dictyoptera: Blattellidae) in multiple-unit dwellings. J. Econ. Entomol. 78: 595–598.

Robinson, W. H, P. A. Zungoli, F. E. Wood, and S. K. Kraft. 1981. The shattering of a myth—cockroach pests in apartments. Pest Control Tech. 9: 38–39.

Schou, C., P. Lind, E. Fernandez-Caldas, R. F. Lockey, and H. Lowenstein. 1990. Identification and purification of a cross-reacting, acidic allergen from American (*Periplaneta americana*) and German (*Blattella germanica*) cockroach. J. Allergy Clin. Immunol. 86: 935.

Sly, R. M. 1988. Mortality from asthma, 1979–1987. J. Allergy Clin. Immunol. 82: 705–717.

Stankus, R. P., W. E. Horner, and S. B. Lehrer. 1990. Identification and partial characterization of important cockroach allergens. J. Allergy Clin. Immunol. 86: 781.

Thoms, E. M., and W. H Robinson. 1987a. Insecticide and structural modification strategies for management of oriental cockroach (Orthoptera: Blattidae) populations. J. Econ. Entomol. 80: 131–135.

1987b. Distribution and movement of the oriental cockroach (Orthoptera: Blattidae) around apartment buildings. Environ. Entomol. 16: 731–737.

Weiss, K. B., and D. K. Wagener. 1990. Changing patterns of asthma mortality: identifying target populations at high risk. J. Am. Med. Assoc. 264: 1683–1687.

Weiss, K. B., P. J. Gergen, and C. F. Crain. 1992. Inner city asthma: the epidemiology of an emerging U.S. public health concern. Chest 101: 362–367.

Wu, C. H., and J. L. Lan. 1988. Cockroach hypersensitivity: isolation and partial characterization of major allergens. J. Allergy Clin. Immunol. 82: 727.

Zhai, J., and W. H Robinson. 1992. Measuring cypermethrin resistance in the German cockroach (Orthoptera: Blattellidae). J. Econ. Entomol. 85: 348–351.

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.

Received for publication 12 June 1996; accepted 18 November 1996.