Attractiveness of Insecticide Baits for Cockroach Control (Dictyoptera: Blattellidae): Laboratory and Field Studies

GODFREY NALYANYA, DANGSHENG LIANG,[1] ROBERT J. KOPANIC, JR.,[2] AND COBY SCHAL

Department of Entomology, North Carolina State University, Raleigh, NC 27695–7613

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ABSTRACT Several insecticide bait formulations were evaluated for their attractiveness to cockroaches in olfactometer assays in the laboratory and in trapping experiments in the field. Included in the assays were bait stations, gels, pastes, and a powder that contained one of the following active ingredients: abamectin, boric acid, chlorpyrifos, or hydramethylnon. There were significant differences among the baits in their attractiveness to the German cockroach, *Blattella germanica* (L.). In trapping experiments, Avert powder (abamectin), Maxforce station and gel, and Siege gel (all hydramethylnon) were consistently attractive to *B. germanica* adults and nymphs. Laboratory olfactometer assays with adult males confirmed these results and showed that nymphs were as responsive as males whereas females were less responsive. Our bioassays also demonstrate that attractiveness of bait can be dramatically affected by the age of the bait. One week of aging significantly reduced the attractiveness of Avert powder in both laboratory and field assays. Aging, however did not diminish the attractiveness of Maxforce gel, indicating that the formulation may be critical for retention of attractiveness of baits. Baits that were most attractive to the German cockroach were also the most attractive to nymphs and adults of the brownbanded cockroach, *Supella longipalpa* (F.).

KEY WORDS *Blattella germanica*, *Supella longipalpa*, baits, cockroach, attractants

MANAGEMENT OF COCKROACH populations in urban environments has recently shifted from the predominant use of insecticide sprays to the inclusion of baits in management programs (Reierson 1995). This change has been facilitated by the general perception that baits are safer and therefore they appeal to the public's concern about risks associated with pesticides in the domestic environment. Moreover, baits fit well into integrated pest management (IPM) objectives of reducing pesticide usage while maintaining effective suppression of cockroach populations (Schal and Hamilton 1990, Rust et al. 1995).

The efficacy of baits is determined by the collective performance of their components, including the active and inert ingredients, food base, odorants, and design in the case of baits housed within a container. Consequently, each constituent of a bait must be evaluated separately to ascertain its effectiveness. Baits have been researched and evaluated extensively, but most of the studies have focused on feeding preferences, insecticide efficacy, repellency, and the overall performance of baits (Milio et al. 1986; Appel 1990, 1992; Schal 1992; Ross 1993; Appel and Benson 1995; Appel and Tanley 2000). Inert ingredients, including a food base, comprise the largest fraction of a bait formulation and they play a vital role of delivering active ingredients to the target pest (Appel 1990, Ross 1993, Rust et al. 1995). They presumably also contain attractants to lure cockroaches to the toxic bait as well as phagostimulants to promote feeding (Silverman and Bieman 1993). Yet, despite the emergence of baits as the preferred cockroach control tactic, few reports have investigated the olfactory responses of cockroaches to baits (Rust and Reierson 1981, Scharf et al. 1994).

The objective of our study was to evaluate the attractiveness of some commonly used baits to two species of cockroaches. Laboratory olfactometer assays and field trapping experiments examined sex- and stage-specific responses of the German cockroach, *Blattella germanica* (L.), effect of bait formulation and age in both two-choice and no-choice assays. We also examined responses of the brownbanded cockroach, *Supella longiplalpa* F., to baits.

Materials and Methods

Insects. An insecticide susceptible strain of *B. germanica*, originally obtained from American Cyanamid (Princeton, NJ) and maintained in the laboratory for >30 yr, was used in these experiments. The colony was maintained at 27 ± 1°C, ambient relative humidity (30–75%), and a photoperiod of 12:12 (L:D) h, and water and Purina Rat Chow (no. 5012, Purina Mills, St. Louis, MO) were provided ad libitum. Male and female cockroaches were separated upon eclosion and reared in separate groups but under similar conditions

[1] Current address: the Clorox Company, Technical Center, P.O. Box 493, 7200 Johnson Drive, Pleasanton, CA 94566.

[2] Current address: SC Johnson Wax, 1525 Howe Street MS165, Racine, WI 53403–2236.

as the rest of the colony. Twenty to 25-d-old adult males, 3-d-old virgin adult females, and 1–5-d-old last instars were used in behavioral assays. *S. longipalpa* was reared under the same conditions as the German cockroaches.

Baits. Eight bait products were purchased from a local distributor and tested. The formulations included powder, dry bait blocks (stations), gels, and pastes, including Avert PT310 crack and crevice bait powder and Avert PT300 aerogel (both with 0.05% abamectin B_1; Whitmire-MicroGen Research Laboratories, St. Louis, MO), It Works Roach Killing paste (52% boric acid; Lo Tox Products International, Mt. Vernon, NY), Magnetic Roach Food paste (33.3% boric acid; Blue-Diamond Exterminating and Manufacturing, Rogersville, TN), MAXFORCE Roach Killer bait gel (2.15% hydramethylnon; Clorox, Oakland, CA), MAXFORCE Roach Killer bait station (2.0% hydramethylnon; Clorox), Raid Max Roach Bait station (0.528% chlorpyrifos; S.C. Johnson & Sons, Racine, WI) and Siege gel (2.0% hydramethylnon; American Cyanamid, Wayne, NJ). White bread (Wonderbread Bakeries, Raleigh, NC), Purina Rat Chow (no. 5012), and a blank control dispenser were also included in bioassays.

Field Experiments. Field trapping experiments were conducted during the summer of 1995 in vacant apartments managed by the Raleigh Housing Authority (Raleigh, NC). Additional refugia, food, and water vials were placed within the apartments and the cockroach infestation augmented with a mixed-population of several thousand adult males, females, and nymphs of laboratory-reared cockroaches at least 7 d before trapping was initiated. Trapping was done in a completely randomized block design with nine treatments (eight baits and a blank control). Each trap consisted of a 0.5-liter glass Mason jar wrapped in a paper towel to facilitate climbing of cockroaches into the trap, and petroleum jelly covered the inside upper wall to prevent trapped cockroaches from escaping. Daily, 0.5 g of bait was dispensed into a plastic cap (1.2 cm diameter by 1.5 cm high) placed inside the jar trap. Nine locations (six on the kitchen floor and three on the living room floor), ≈1.25 m apart and 30 cm away from any wall or furniture, were selected for trapping. The baited traps were left in place for 24 h and replaced daily with freshly baited traps. The locations of traps were rerandomized daily over 9 d, and the number of trapped males, females, and nymphs was recorded. A similar study was conducted with *S. longipalpa.*

Laboratory Olfactory Assays. A series of two-choice olfactometers was used for the behavioral assays. Each olfactometer consisted of a Plexiglas tube (54.5 by 3.2 cm i.d.) with a 15 cm long divider sealed vertically in the upwind end. A cage (15 by 3.2 cm i.d.) with a swivel metal screen gate was used to introduce cockroaches from the downwind end of the olfactometer (Liang and Schal 1993). Sixteen such olfactometers were connected to a vacuum pump that provided a linear air velocity of 25 cm/s through each tube during the assay. Fluorescent lights covered with red photographic filters placed 60 cm below and above the olfactometers facilitated observation in the dark. Baits were placed in open containers in a fume hood for 24 h after which 0.1 g of each bait was placed in a 1.5-ml microcentrifuge tube and tested during the scotophase. Three cockroaches were acclimated for 30 min in the downwind cage of each olfactometer tube. The bait and blank control dispensers were introduced at the upwind end of the olfactometer and insects were observed and their responses recorded. A positive response was recorded when the cockroach walked upwind within 1 min. Forty five to 48 adult cockroaches and 45–78 nymphs were used for each bait type. Male cockroaches were used initially to determine the attractiveness of the baits, bread, rat chow, and a blank control dispenser. Based on results for males, the four most attractive baits were then tested with 3-d-old adult females and 1- to 5-d-old last instars. Cockroaches were used only once and discarded.

Effects of Aging of Baits on Attractiveness to Cockroaches. Two formulations, a powder (Avert PT310) and a gel (Maxforce gel), were selected to test the effect of aging because these baits attracted cockroaches consistently in both field and laboratory experiments. The baits were aged for 7 d in a fume hood. Two types of behavioral assays were conducted with aged baits. The first was a no-choice olfactometer assay that examined responses to either fresh or aged baits; a positive response consisted of upwind movement toward the bait within 1 min. The second was a two-choice assay in which the fresh and aged baits were presented simultaneously with positive responses consisting of upwind orientation and choosing one or the other bait within 1 min.

A field trapping study was also conducted to determine the effect of age on attractiveness of baits. In the trapping study six traps (3 traps containing fresh bait and three aged bait) were placed for 24 h in a vacant apartment, as described earlier. Thereafter the traps were replaced by freshly baited traps, for 24 h, with the location of the treatments reversed.

Statistics. Trap catches from field studies with *B. germanica* were subjected to square-root transformation and analyzed by analysis of variance (ANOVA) and univariate repeated measures ANOVA using PROC GLM (SAS Institute 1997). Because of imbalance in design, the LSMEANS/PDIFF option in PROC GLM (SAS Institute 1997) was used to compute and separate differences in the mean trap catch of baits. Cockroach response to baits in the initial olfactometer assays were analyzed by Ryan's test (Ryan 1960). Bait choice by cockroaches in aging studies was analyzed by the χ^2 test. In the trapping experiments involving *S. longipalpa*, trap catches were subjected to PROC GLM (SAS Institute 1997) and the means separated by least significant difference (LSD). For all statistical tests $\alpha = 0.05$ and we report variation around the mean as SE.

Results

Comparative Attractiveness of Baits. *Field Trapping.* The repeated measures ANOVA indicated that there

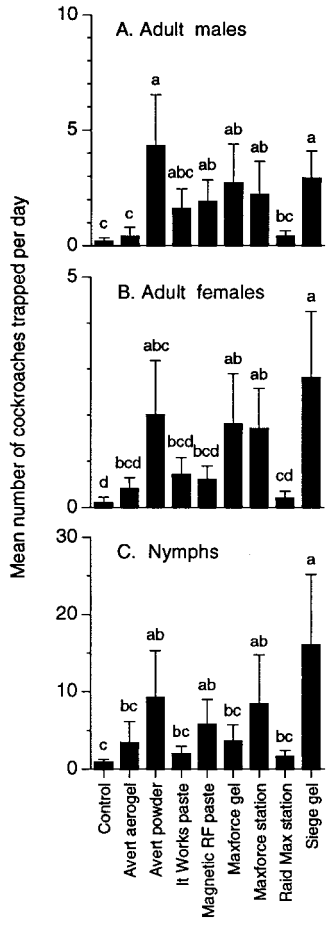

Fig. 1. Mean ± SE number of German cockroaches trapped per day in traps baited with various baits. Bars with different letters are significantly different (n = 9; LSMEANS/PDIFF; $P < 0.05$).

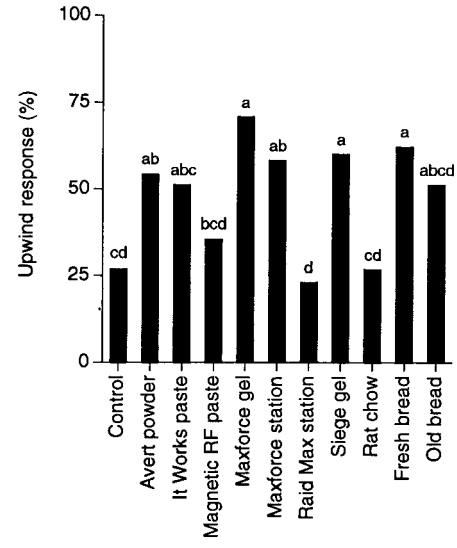

Fig. 2. Olfactometer responses of adult male *Blattella germanica* to baits. Bars with different letters are significantly different (n = 42–48 for each bait; Ryan's test $P < 0.05$).

was no significant daily variation in the performance of any of the baits (F = 1.7; df = 8, 56; P = 0.057). However, there were significant differences among the life stages that were trapped (F = 31.4; df = 2, 56; $P < 0.001$) and the numbers of cockroaches trapped in different locations within the apartment (F = 23; df = 8, 56; $P < 0.001$). The stage by location interaction was also significant (F = 4.35; df = 16, 112; $P < 0.001$), but the stage by bait interaction was not (F = 1.56; df = 16, 112; P = 0.092).

There were significant differences among the baits in their attractiveness to adult males (F = 2.67; df = 8, 56; $P < 0.05$), adult females (F = 2.75; df = 8, 56; $P < 0.05$) and nymphs (F = 2.45; df = 8, 56; $P < 0.05$) (Fig. 1), as well as to the total number of cockroaches trapped by each bait (F = 3.44; df = 8, 56; $P < 0.05$). Avert powder, Maxforce gel, Maxforce station and Siege gel, trapped the most male cockroaches but not significantly more than It Works paste and Magnetic Roach Food paste (Fig. 1A). In contrast, Avert aerogel, It Works paste, and Raid Max station did not differ significantly from the blank control in their attractiveness to males. The baits that attracted more males also trapped more adult females (Fig. 1B). Avert powder, Maxforce gel, Maxforce station, and Siege gel trapped approximately the same number of females and significantly more than the blank control traps. Catches of female cockroaches by Avert aerogel, It Works, Magnetic Roach Food, and Raid Max, however, were not significantly different from catches in the blank control traps. For nymphs, Avert powder, Maxforce station, Magnetic Roach Food, and Siege gel trapped more than the control jars, whereas Avert aerogel, It Works, Maxforce gel, and Raid Max station did not attract significantly more nymphs than did the blank control jars (Fig. 1C).

Olfactometer Assays. In binary-choice behavioral assays with adult male *B. germanica*, 20 out of 75 males (26.7%) exited their cage in response to two empty control dispensers; of these, 52.6% chose the right and 47.4% the left side of the two-choice olfactometer. Upwind orientation responses to the seven baits ranged from 22.9% in response to Raid Max station to 70.8% to Maxforce gel (Fig. 2). Avert powder, Maxforce gel, Maxforce station, and Siege gel elicited upwind orientation in a significantly greater percentage of males than the blank control while male responses to It Works, Magnetic Roach Food paste, and Raid Max station were not significantly different from responses to the blank control (Fig. 2). Of the males that made a choice between the bait and a blank dispenser, only 62.5% (5 of 8) chose Raid Max station and between 85.2% (Siege gel, 23 of 27) and 100% (Avert powder, 26 of 26; It Works paste, 19 of 19) of the males chose each of the other baits. Also, more males responded positively to fresh bread than to the odor of rat chow.

The baits that were most attractive to males in field and olfactometer experiments (Avert powder, Max-

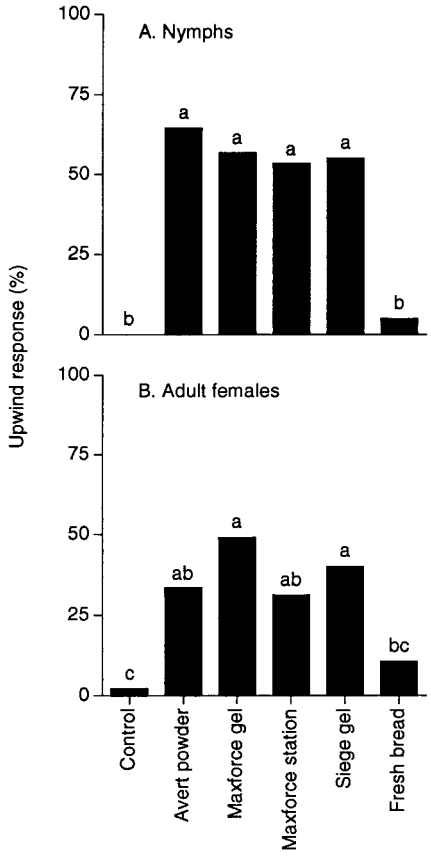

Fig. 3. Olfactometer responses of nymphs and adult females to baits. Bars within each life stage with different letters are significantly different ($n = 42$–48 for each bait, $n = 72$ for control; Ryan's test, $P < 0.05$).

force gel, Maxforce station, and Siege gel) were also tested with females and nymphs. The behavioral responses of nymphs and adult females ranged from 0 to 64 and 2 to 49%, respectively (Fig. 3). Thus, in the olfactometer nymphs and males generally exhibited higher responses than did females, as also seen in the field trapping experiments. Avert powder elicited the highest response from nymphs while Maxforce gel elicited the highest percentage response from female cockroaches. There were, however, no significant differences in attractiveness of the four insecticide baits to either nymphs or to females (Fig. 3). In contrast to the males, nymphs and adult females were not more attracted to fresh bread than to the control.

Aging of Baits. In trapping experiments, aging the baits for 7 d reduced the attractiveness of Avert powder to adult males ($F = 7.47$; df = 1, 11; $P < 0.05$) and adult females ($F = 6.75$; df = 1, 11; $P < 0.05$), but not to nymphs ($F = 1.96$; df = 1, 11; $P = 0.195$); the total of all trapped cockroaches was reduced by 66% ($F = 9.73$; df = 1, 11; $P < 0.05$) (Table 1). Surprisingly, aged Maxforce gel lured 40% more cockroaches than the fresh bait ($F = 6.10$; df = 1, 11; $P < 0.05$). When each stage and sex was analyzed separately, however, there was no significant difference in the trap catch of aged and fresh bait. The results of the field trapping experiments were confirmed by olfactometer assays. Aging the bait significantly reduced the attractiveness of Avert powder to adult males in both no-choice and in two-choice experiments (Fig. 4 A and B). In contrast, there was no significant difference in the attractiveness of fresh and aged Maxforce gel bait (Fig. 4 C and D), although the latter was preferred after aging 1 wk. As predicted from previous results, fresh and aged Avert powder and Maxforce gel elicited strong upwind responses (40 out of 48 and 37 out of 48, respectively) in 2-choice assays. Taking into account only the males that responded, Avert powder was clearly more attractive when fresh but the attractiveness of Maxforce gel was retained and even increased upon aging in a fume hood.

Attractiveness of Baits to Brownbanded Cockroaches in the Field. There was a significant effect of bait type on the number of trapped adult males ($F = 3.31$; df = 8, 64; $P < 0.05$), females ($F = 2.22$; df = 8, 64; $P < 0.05$), nymphs ($F = 3.52$; df = 8, 64; $P < 0.05$), as well as on the total number of cockroaches trapped by each bait ($F = 3.57$; df = 8, 64; $P < 0.05$). Avert powder was the most attractive bait for both adults and nymphs of this species (Fig. 5). Maxforce station and gel were also numerically more attractive than the other baits but they failed to attract significantly more cockroaches than the blank control.

Discussion

There is generally a lack of consensus among researchers on the relative importance of odors in cockroach orientation within infested homes. Male cockroaches (e.g., *S. longipalpa*) effectively orient to female sex pheromones (Liang et al. 1998), clearly demonstrating that chemoreception operates in both

Table 1. Mean number (±SE) of *Blattella germanica* of various stages trapped by fresh and aged Avert powder and Maxforce gel ($n = 6$ traps per bait)

Stages	Avert PT310 powder			Maxforce gel		
	Fresh	Aged	P^a	Fresh	Aged	P^a
Male	7.5 ± 2.3	1.0 ± 0.4	<0.05	5.5 ± 1.1	7.7 ± 1.7	0.195
Female	2.5 ± 0.8	0.5 ± 0.2	<0.05	2.5 ± 0.8	3.3 ± 0	0.387
Nymph	9.5 ± 3.3	5.2 ± 1.6	0.195	31.5 ± 5.7	44.3 ± 10.7	0.125
All cockroaches	19.5 ± 5.8	6.7 ± 1.6	<0.05	39.5 ± 6.2	55.3 ± 11.0	<0.05

[a] Statistical analysis based on ANOVA.

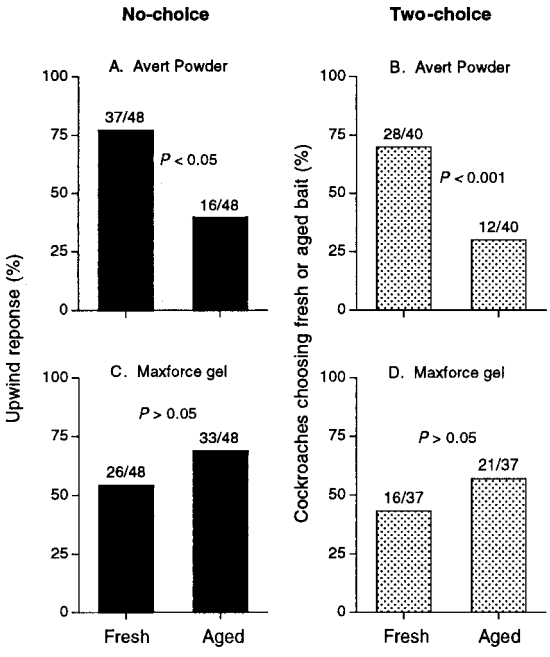

Fig. 4. Comparison of behavioral responses of adult male *Blattella germanica* to fresh and aged baits in no-choice and two-choice assays. The no-choice response examines the percentage of cockroaches that oriented upwind. The two-choice assay examines the percentage of responding males that chose the fresh versus aged bait (i.e., the two bars add up to 100%). The proportion of cockroaches responding is indicated above the bars and the results of χ^2 tests are indicated between bars.

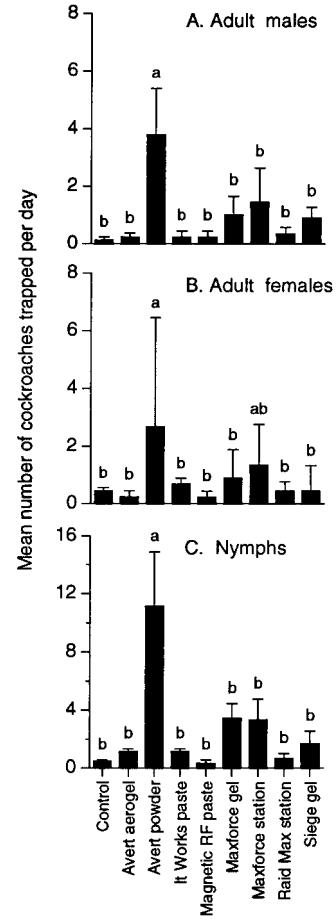

Fig. 5. Mean ± SE number of brownbanded cockroaches, *Supella longipalpa*, trapped per day in traps baited with various baits. Bars with different letters are significantly different ($n = 9$; LSD; $P < 0.05$).

olfactometer and field trapping experiments. Yet, cockroaches are thought to be incapable of detecting food odors over more than "a few" centimeters (Meisch and Howell 1967, Reierson 1995) and the predominant view is that cockroaches locate food (and thus eat baits and enter traps) during random foraging. Our results now extend the observations on sex pheromones to food-based odorants. The olfactometer results show that orientation to attractive baits is mediated by olfaction over some distance. Cockroaches that responded to these baits made oriented upwind movements toward the odor source and they effectively discriminated between odorants. Furthermore, we show that some insecticide baits contain odorants that serve as attractants (sensu Dethier et al. 1960) and thus mediate oriented movements by cockroaches toward the odor source. The field trapping experiments confirmed that some baits attracted more cockroaches to traps than the blank control lure. This was despite highly significant trap location effects that are common in cockroach trapping in apartments, and our deliberate placement of traps away from normal foraging paths along walls. Together, these results suggest that, as for sex pheromones, these food odorants attracted cockroaches over some distance to less favorable locations. In addition, the congruence in the results from laboratory behavioral assays and field trapping studies suggests that laboratory olfactometer assays can serve as a reliable tool for screening cockroach attractants, including bait formulations.

This view is also supported by the response of cockroaches to bread. Several studies have examined the attractiveness of various food stuffs and chemicals to cockroaches (Tsuji 1966; Sugawara et al. 1975a, 1975b; Reierson and Rust 1977; Rust and Reierson 1981; Ballard and Gold 1982; Wileyto and Boush 1983; Brenner and Patterson 1989; Brenner and Pierce 1991; Pandey et al. 1994, 1995), and bread has emerged as one of the most attractive food substances; it is frequently used in trapping studies in apartments, often mixed with beer (Owens and Bennett 1982, 1983; Barcay et al. 1990). Bread was highly attractive in our olfactory assays (Fig. 2), only second to Maxforce gel in attracting male *B. germanica.* These results show that although some of the commercial baits are quite attractive, they are not much more attractive than some domestic food substances.

The baits tested in this study were not equally attractive to *B. germanica.* Avert powder, Siege gel, Max-

force gel, Maxforce station, and It Works paste consistently attracted more cockroaches than the control in both field (Fig. 1) and laboratory olfactometer assays (Fig. 2). Nevertheless, even the best performing baits elicited responses from only 51.1% (It Works paste) to 70.8% (Maxforce gel) of the cockroaches in laboratory assays. With respect to adult male cockroaches, these results suggest that the odorants in the tested baits are relatively ineffective compared with even crude extracts of the sex pheromone of *B. germanica* (see Liang and Schal 1993). Because the available sex pheromones attract only males, pheromones can be integrated with food attractants to attract females and nymphs (Landolt et al. 1997, Liang et al. 1998).

The results from trapping *B. germanica* in the field, and assays in the laboratory, were remarkably consistent. Avert powder, Siege gel, and Maxforce gel and station were not significantly different from each other but consistently more attractive than the blank control to both nymphs and adults. In the field, the order of decreasing trap catch was nymphs > males > females (Fig. 1), whereas in laboratory studies the order of decreasing response was males > nymphs > females (Figs. 2 and 3). The life stage by bait interaction in the trapping study was not statistically significant, suggesting that nymphs and adults were equally attracted and trapped by the same baits. Together with the observation that baits that attracted the German cockroach also lured brownbanded cockroaches to traps (Fig. 5), these data suggest that some of the more attractive baits used in these experiments (i.e., those in Fig. 3) contained general, nonspecies-specific food attractants.

Because attractants in baits would be expected to increase the rate of encounters and contacts between cockroaches and baits, it follows that they should enhance the efficacy of the more attractive baits, assuming that the baits are equally palatable. Yet adult females, which represent an important target for baiting programs, were the least responsive to the baits. This finding might reflect the fact that most females in normal cockroach populations would be expected to be carrying oothecae and therefore feeding little (Cochran 1983, Schal et al. 1997). The olfactometer assays (Fig. 3), however, were conducted with 3-d-old females that exhibit some of the highest rates of food intake of any physiological stage. Again, these data suggest that the attractiveness of baits to females can be significantly improved.

We placed the traps >30 cm away from normal foraging paths (e.g., walls, appliances). Even so, the effect of trap location on trap catch was highly significant for nymphs and adults of both species. Cockroaches prefer certain microhabitats and are therefore unevenly distributed in the heterogeneous environment within apartments (Schal and Hamilton 1990, Metzger 1995). Consequently, traps placed nearest to these microhabitats and cockroach aggregations may capture more cockroaches (Appel and Reid 1992) regardless of the attractant in the trap. Location effects could therefore be attributed to a general lack of potency of the attractants within these baits, thus favoring whichever trap is nearest the aggregation. This is consistent with the finding that the efficacy of baits was higher when the number of bait stations within the structure was increased (Milio et al. 1986, Reierson 1995). Furthermore, pest control technicians are advised to place baits close to cockroach aggregations to enhance detection and accessibility of the bait and consequently increase the chances of cockroaches encountering and feeding on the bait. Notwithstanding, the emergence of several baits as more highly attractive in a randomized block design, despite a strong trap location effect, clearly contends that these baits contain odorants that enhance trap catch.

Insecticides should be formulated to maximize delivery of the active ingredient to the target pest. Baits strive to accomplish this by attracting cockroaches, stimulating feeding, and maximizing absorption of the active ingredients through the digestive system. Whereas the formulation type can greatly alter bait efficacy (see Appel 1992, Appel and Benson 1995, Reierson 1995), it did not appear to have any particular influence on the attractiveness of the baits. The five most attractive bait formulations included a powder (Avert PT310), gels (Maxforce, Siege), a dry bait (Maxforce station), and a paste (It Works). The moisture content of gels and pastes is relatively high compared with powder and solid baits (Appel 1992, Appel and Benson 1995); therefore, under our field and laboratory conditions moisture content may not have a direct effect on bait attractiveness to cockroaches. Other bait ingredients may also influence attraction to formulated baits. Although Avert powder and gel appear to be composed of essentially the same ingredients, the two formulations have different characteristics, including water content. Yet, the powder formulation was much more attractive to cockroaches than the gel. It is possible that excess water may diminish the release of odorants or that other formulation ingredients, possibly repellents, interfere with the attractiveness of baits. The latter is evident in Raid Max station which failed to attract either *B. germanica* in the field (Fig. 1) and in olfactometer assays (Fig. 2) or *S. longipalpa* in the field (Fig. 5), possibly due to repellency of the active ingredient chlorpyrifos (Rauscher et al. 1985, Appel 1990).

The physico-chemical properties of baits determine the rate at which odorants are released (Darling et al. 1986). To effectively control cockroaches, baits should remain attractive and palatable after their deployment. The decline in attractiveness and palatability may involve desiccation and chemical degradation of bait ingredients, including the active ingredients. Avert powder was adversely affected by 7 d of aging in a fume hood, as shown by olfactometer assays (Fig. 4), but the attractiveness of Maxforce gel was not affected by aging. These results were corroborated in the field, where trap catches were significantly increased by aged Maxforce gel and significantly diminished by aged Avert powder (Table 1). It is possible that gel baits retain attractants more effectively than other formulations and might continue to attract cock-

roaches for some time after application. The enhanced attractiveness of the aged gel also suggests that fresh gel might release chemicals that interfere with olfactory orientation toward the bait.

In conclusion, we have shown that cockroaches respond to olfactory cues that emanate from baits. Their oriented upwind responses in olfactometer assays are generally good predictors of the attractiveness of the bait in the field. Differential attraction of cockroaches to various baits in traps suggests that cockroaches are attracted to baits over some distance. However, whereas some baits are quite attractive to male cockroaches, none is significantly more attractive than bread. Therefore, to increase the probability and frequency of contact between cockroaches and baits, and to diminish chance encounters from determining the efficacy of insecticide baits, more potent long-distance attractants should be incorporated into baits. Baits should also contain ingredients that interact to maximize palatability, stability of attractants in various ambient conditions, and enhance attractiveness by regulating the rate of attractant release. In addition to the inherent advantages of attractive baits, effective lures could be used in traps to detect, monitor, and mass trap cockroaches, as well as in "attract-and-kill" and "push-pull" strategies that integrate the use of attractants, repellents and insecticides (Nalyanya et al. 2000). Ultimately, more attractive baits could reduce the use of insecticides by reducing the area of a structure requiring insecticide treatment.

Acknowledgments

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