Comparison of Cockroach Traps and Attractants for Monitoring German Cockroaches (Dictyoptera: Blattellidae)

CHANGLU WANG[1] AND GARY W. BENNETT

Center for Urban and Industrial Pest Management, Department of Entomology, Purdue University, West Lafayette, IN 47907

Environ. Entomol. 35(3): 765–770 (2006)

ABSTRACT Studies were conducted in large arenas and simulated kitchens to compare the effectiveness of eight traps (seven sticky traps and one jar trap) and five attractants for monitoring German cockroaches (*Blattella germanica* L.). The evaluated traps were Trapper (type 9110–1), Catchmaster 150, 1001, and 2881, Victor-M330, Victor-M327, Glue board in D-Sect station, and a baby food jar trap. In choice tests, Victor-M330 consistently caught the most and Catchmaster 150 caught the fewest cockroaches. Numbers in the Victor-M330 were 78- and 36-fold greater than in the Catchmaster 150 in the large arena and simulated kitchen experiments, respectively. Sticky traps caught proportionally more small nymphs than large nymphs. Baby food jar trap samples had significantly greater adult/total ratio and large nymph/nymph ratios than the sticky trap samples. In addition, baby food jar trap catches had significantly lower male/adult ratio than Catchmaster 1001 and Victor-M327 trap catches. Flat Trapper traps caught significantly more cockroaches than the assembled (triangular) Trapper traps. Bread with beer, peanut butter, Trapper roach attractant, NAF430 gel bait, and Invite lure were compared in choice tests for their effect on sticky trap catches in simulated kitchens. All attractants significantly increased the number of cockroaches trapped in sticky traps compared with an unbaited trap. Bread with beer was by far the most attractive bait, increasing trap catches by 34-fold over the unbaited control. Baited sticky traps may have much greater efficacy than nonbaited traps for monitoring and controlling German cockroach infestations.

KEY WORDS *Blattella germanica*, sticky traps, jar traps, attractants

Sticky traps are frequently used by homeowners, pest management professionals, and researchers for monitoring infestations of cockroaches, as well as other crawling insects such as ants, spiders, sow bugs, millipedes, and beetles (Ebeling and Reierson 1974, Barak et al. 1977, Moore and Granovsky 1983, Owens and Bennett 1983). They provide consistent estimates of German cockroach, *Blattella germanica* L., relative abundance in the environment (Ballard and Gold 1983, Appel 1998). In addition to monitoring purposes, sticky traps are useful for evaluating insecticide efficacy and reducing populations of German cockroaches (Owens and Bennett 1983, Kaakeh and Bennett 1997). As a monitoring tool, sticky traps provide information on cockroach distribution and population density, thereby assisting in properly targeting insecticide applications (Kardatzke et al. 1981). Because of their safety, ease of use, and nontoxicity, sticky traps are considered to be a valuable tool in cockroach integrated pest management (IPM) programs.

Jar traps also can be used for monitoring German cockroaches. The jars used were either 0.943-liter-wide mouth mason jars or 0.124-liter baby food jars (Artyukhina 1972, Reierson and Rust 1977). Food (bread and/or beer) was placed in jars to attract cockroaches. An impassable barrier (clay powder or grease) was applied to the inner surface to prevent escape. Monitoring cockroach infestations with jar traps is nondestructive (does not kill cockroaches) and therefore provides an advantage over sticky traps in estimating population sizes. Jar traps are cheaper than sticky traps and are reusable. However, they are less convenient compared with sticky traps because of their size and the time needed for preparation.

Traps differ greatly in design features such as shape, size, surface material around the edge of the glue area, and presence of attractants. The efficacy and bias of traps can be influenced by their design and placement method. Owens and Bennett (1983) compared jar traps with sticky traps and visual count methods. They concluded that the jar trap designed at the University of California, Riverside generated the most accurate information on age structure of German cockroach populations. However, it was also the least effective in trapping German cockroaches. Traps placed against

[1] Corresponding author: Department of Entomology, Purdue University, 901 W. State Street, West Lafayette, IN 47907 (e-mail: changluw@purdue.edu).

Table 1. Descriptive information on the eight traps studied in arenas and simulated kitchens

Abbreviation	Name	Description	Manufacturer
Trapper	Trapper Monitor & Insect Trap (type 9110–1)	Not baited, forming a isosceles triangle after assembled, 7.6 by 6.2 cm glue area, one 2.9 by 1.0 cm window on each side.	Bell Laboratories, Inc., Madison, WI.
C-150	Catchmaster 150 RI IPM Tool for Roaches and Insects	With peanut butter/molasses bait, rectangular after assembled, 14.0 by 7.0 cm glue area, no window on the top or sides.	Atlantic Past & Glue Co., Inc., Brooklyn, NY.
C-1001	Catchmaster 1001 Insect Trap and Monitor	With peanut butter/molasses bait, forming a right triangle after assembled, 11.1 by 6.5 cm glue area, one 3.8 by 1.6 cm window on the side.	Atlantic Past & Glue Co., Inc., Brooklyn, NY.
C-2881	Catchmaster 2881 Insect Trap and Monitor	With peanut butter/molasses bait, rectangular after assembled, 7.6 by 5.6 cm glue area, two 3.8 by 1.6 cm windows on the sides.	Atlantic Past & Glue Co., Inc., Brooklyn, NY.
D-Sect	D-Sect Station with Custom Glueboard	With food scent, rectangular station (15.9 by 8.9 by 1.6 cm) with openings on each side, 11 by 5.5 cm glue area.	Rockwell Labs Ltd, Minneapolis, MN.
V-M327	Victor-M327 Roach & Insect Glue Trap	With food scent, forming a right triangle after assembled, 8.5 by 5.0 cm glue area, two 3.7 by 1.6 cm windows on one side.	Woodstream, Lititz, PA.
V-M330	Victor-M330 Roach & Insect Glue Trap	With roach pheromone, rectangular, 4.7 by 4.0 cm glue area, with plastic film on edge of glue area, one 3.7 by 1.4 cm window on the side and one 3 by 3 × 4.5 cm triangular window on the top.	Woodstream, Lititz, PA.
Jar	Baby food jar trap	With bread and beer, 6.5 cm tall, 4.5 cm opening, 124 ml vol, inner upper surface of the jar was coated with petroleum jelly and mineral oil (2:3).	

vertical surfaces were more efficient in trapping German cockroaches (Owens 1995). Food and pheromone can increase trap catches (Ebeling and Reierson 1974, Ballard and Gold 1982, Kaakeh and Bennett 1997). This kind of information is useful for obtaining the best results when using traps to monitor cockroaches.

Various attractants (food, food scent) are incorporated into traps to increase their efficacy. Ebeling and Reierson (1974) reported that white bread was more attractive than beef to German cockroaches. It increased jar trap catches by 7.6-fold. In a field study, Ballard and Gold (1982) found that white bread was superior to dog food, cockroach feces, apple, yeast, and Mr. Sticky Chrysalis powder when the Mr. Sticky trap was used. Piper et al. (1975) showed that banana peel can attract German cockroaches to jar traps. Kaakeh and Bennett (1996) indicated that Victor traps with aggregation pheromone trapped significantly more cockroaches than Victor traps without pheromone. However, Smith and Appel (2002) reported that cockroach aggregation pheromone had no detectable effect on trap catches. Previous research has shown that German cockroaches are not attracted to the food or scents discussed above over a few centimeters (Rust and Reierson 1981). Nalyanya and Schal (2001) compared various attractants in olfactomer assays and field experiments. Inconsistent results were found between olfactometer bioassays and field experiments. Peanut butter, distiller's grain, and AgriSense GP-2 were found to be useful when placed in jar traps to attract cockroaches.

We compared the catch in cockroach traps in choice experiments in two laboratory settings. Specifically, we tried to (1) compare the quantity of cockroaches captured in traps used for monitoring German cockroach populations and test for age bias in captures; (2) compare attractants in terms of trap captures; and (3) determine the effect of trap shape on trap captures.

Materials and Methods

One glass jar trap and seven sticky traps were tested (Table 1). Five attractants were evaluated as follows: creamy peanut butter (J. M. Smucker Co., Orrville, OH), white bread (Kroger Co., Cincinnati, OH) with Miller Lite beer (Miller Brewing Co., Milwaukee, WI), NAF430 gel bait (Dow AgroSciences, Indianapolis, IN), Invite lure (Rockwell Labs, Minneapolis, MN), and Trapper roach attractant (Bell Laboratories, Madison, WI). NAF430 is a cockroach gel bait recently developed by Dow AgroSciences (Wang and Bennett 2004). Invite lure and Trapper roach attractant are two cockroach baits sold in the United States for increasing trap efficacy. All baits tested do not contain insecticidal ingredients.

Comparative Catch in Traps in 1 by 1-m Arenas. The experiment was conducted in 1 by 1-m arenas constructed from Plexiglas walls and particle board floor with a white painted surface. A thin layer of petrolatum and mineral oil (2:3) was applied to arena walls within 5–10 cm of the arena floor to prevent escape. Each arena contained two harborage units consisting of five (10 by 10 cm) plywood panels separated by 5-mm spacers, mixed food (rodent chow, peanut oil on filter paper, grape jelly), and water. The arenas were located in a room at 27°C, 38% RH, and a photoperiod of 12:12 (L:D) h. Five hundred Jwax (a laboratory strain) cockroaches were released into each arena: 250 small nymphs (second to third instar), 125 large nymphs (fourth to fifth instar), 65 adult males, and 60 nongravid adult females. After 3 h of acclimation, eight different traps were placed in each of the 10 arenas, with two traps along each wall. The traps were randomly placed against the four walls of the arena with ≈30 cm distance between the two neighboring traps along each wall. The traps were replaced daily for 8 d. On each day, the eight types of traps in each arena were randomly placed against a wall of the arena. Trap catches were recorded as small and large nymphs, adult males, and adult females. The remaining number of cockroaches in each arena at 8 d was recorded.

Comparative Catch in Traps in Simulated Kitchens. Four simulated kitchens located in the basement of the Whistler Hall of Agricultural Research building at Purdue University were used in this experiment. The environmental conditions were 25.2–30.3°C, 23.2–53.6% RH, and a photoperiod of 12:12 (L:D) h. The kitchens (3.05 length by 1.83 width by 2.67 height in meters) were made of wood panels. Each kitchen had two cabinets (150 by 60 by 85 cm) on the floor and one cabinet (75 by 30 by 15 cm) on the wall. Cardboard rolls and a cardboard box were provided as harborages. Two water jars (476 ml each) with cotton wicks and six food placements (each with peanut oil, grape jelly, and rodent chow) were provided as water and food sources. Approximately 1,500–2,500 mixed stages of German cockroaches (mixed laboratory and field strains) were released in each of the four kitchens 7 d before the placement of traps.

Two sets of traps were placed in each kitchen: one on top of a cabinet and one on the kitchen floor. The eight traps in each set were arranged in a circle around a corrugated cardboard roll, food, and water. The diameter of the circle on the cabinet was ≈50 cm. The diameter of the circle on the floor was ≈90 cm. The open ends of the sticky traps were oriented toward the center of the circle. The traps were replaced daily for 3 d. On each day, the traps in each circle were placed randomly. Trap catches were recorded as small and large nymphs, adult males, and adult females.

Comparison of Attractants. The effect of five attractants on catches in Trapper sticky traps was evaluated in four simulated kitchens. The attractants were (1) white bread (2 by 2 cm) with beer (2 ml); (2) Invite lure (0.5 g); (3) Trapper roach attractant (0.19 g, one piece); (4) NAF430 (0.5 g); and (5) peanut butter (0.5 g). A Trapper trap without attractant was used as control. The attractant was placed in the center of a small Trapper trap (7.6 by 6.2-cm glue area). Two sets of traps were placed in each kitchen: one on the cabinet top and one on the floor. Each set contained six traps with different attractant types (five attractants and a control). The traps were replaced daily for 2 d. On each day, the traps were randomly arranged in two circles as in the previous experiment. The number of small and large nymphs, adult males, and adult females in each trap were recorded.

Effect of Trap Shape on Captures. The relative catch in the flat and assembled Trapper traps was evaluated in four simulated kitchens. The assembled Trapper trap formed a triangular "tent" with a window on each side panel. One of the bottom edges of the "tent" was folded upward (8 mm high) along a precreased seam. The flat trap did not have the side panels. Two sets of traps were placed in each kitchen: one on the cabinet top and one on the kitchen floor. Each set consisted of three flat and three assembled traps, which were arranged alternately. They were replaced with new traps daily for 3 d. The number of trapped cockroach nymphs, adult males, and adult females were recorded daily.

Data Analysis. The trap count data were logarithmically transformed before the analysis of variance. Mixed models (PROC MIXED) or generalized linear models (PROC GLM) were used to evaluate the effect of trap type, attractant, shape, kitchen, and location on trap catches, male ratio (male/adults), nymphal ratio (nymph/total), and large nymph ratio (large nymph/nymph) where applicable (SAS Institute 2001). The ratio data were not transformed before analysis because their variances were homogeneous. The mixed model was used when "day" variable was considered as a random effect. Means among the treatments were separated by Tukey's test. Control and treatment means (attractant) were separated by Dunnett's test. Mean large nymph/nymph ratios in the arena experiment were compared with the ratio in the population using Student's *t*-test. The male ratio in the arena experiment was not compared with those in the population because the trap catches were too small.

Results and Discussion

Comparative Efficacy of Traps. In the 1 by 1-m arena experiment comparing various traps, significant differences were found among traps in trap catches ($F = 26.2$, df = 16,63; $P < 0.001$). V-M330 caught the most number of cockroaches and C-150 caught the fewest (Fig. 1A). The relative catch in V-M330, Trapper, V-M327, C-1001, D-Sect, C-2881, Jar, and C-150 was 78, 18, 16, 9, 4, 4, 3, and 1 based on the mean trap catches in an 8-d period. On average, 63.6 ± 1.5% (SEM) of cockroaches in each arena were trapped based on cumulative trap catches and the remaining number of cockroaches in the arenas after 8 d.

In the kitchen experiment, the ratio of captures in V-M330, Trapper, V-M327, C-1001, D-Sect, C-2881, Jar, and C-150 was 36:17:13:9:13:3:7:1 based on average daily catches per trap (Fig. 1B). Similar to results in the arena experiment, there were significant differences among the traps in trap catches ($F = 26.9$; df = 7,178; $P < 0.001$; PROC MIXED with trap, kitchen, location as fixed effect and day as random effect). V-M330 caught the most cockroaches and C-150 caught the fewest. C-150 was the only trap without openings on the two side panels or on the top, which might explain the lower numbers caught compared with other traps. Cockroaches were observed to enter traps through openings on side panels or the top of the

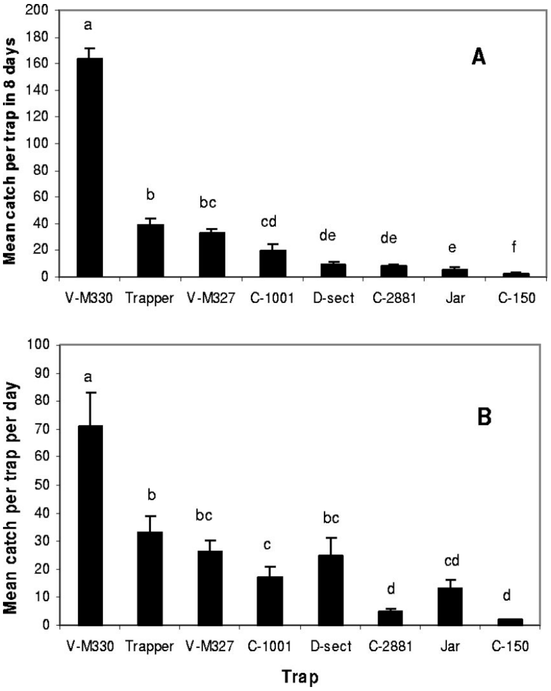

Fig. 1. Captures in choice tests of traps designed for monitoring German cockroaches. Bars (mean ± SEM) with letters in common are not significantly different (Tukey's test, $\alpha = 0.05$). (A) In 1 by 1-m arenas ($n = 10$). (B) In simulated kitchens ($n = 24$).

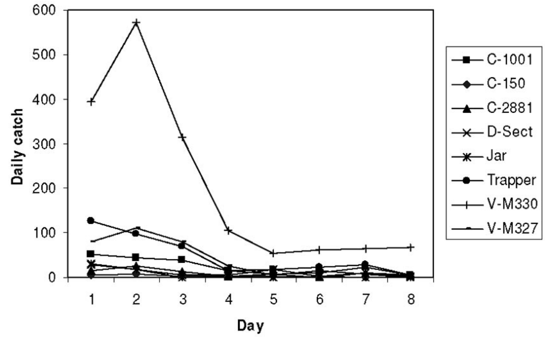

Fig. 2. Daily total number of trapped German cockroaches in the arena experiment ($n = 10$).

sticky traps. V-M330 has 1- to 1.5-cm-wide plastic film around the glue area and a pheromone-impregnated wood chip. The plastic film provides less traction for cockroaches. Therefore, cockroaches were less likely to escape after running into the sticky surface. The pheromone wood chip might also have contributed to the higher number of catches (Kaakeh and Bennett 1996). However, Nalyanya and Schal (2001) found Victor pheromone did not increase trap catches in apartment and swine farm experiments.

Daily trap catches by V-M330 in the arena experiment decreased sharply over the first 3 d and remained stable after 4 d as a result of large numbers of cockroaches being removed from each arena. During days 5–8, V-M330 trapped an average of 3.7% of the remaining cockroaches per day (Fig. 2). The mean remaining numbers of cockroaches in the arenas during 5–8 d were 182 ± 8, 169 ± 8, 153 ± 6, and 158 ± 6, respectively. The data suggest that, when cockroach population density is low, none of the tested sticky traps can effectively reduce cockroach numbers. This corroborates previous field experiment conclusions that sticky traps could not effectively control cockroach infestations (Ballard and Gold 1983, 1984).

Effect of Trap Types on Population Age Structures of the Trapped Cockroaches. Besides differences in their efficacy, traps also differed in the age structures of the trapped cockroaches. The nymphal ratios (nymph/total) from the first 2 d of trapping in the arena experiment were calculated. The trap catches beyond 2 d was not included because of the natural changes in nymphal ratios. Only those observations with at least 10 trapped roaches were used. The mean nymphal ratios in V-M330, Trapper, and V-M327 were 0.83 ± 0.02 ($n = 10$), 0.79 ± 0.03 ($n = 9$), and 0.71 ± 0.07($n = 8$), respectively. The other traps were not analyzed because they had less than five valid replicates. The nymphal ratio of the populations when released to the arenas was 0.75. The ratio from the V-M330 was significantly higher than the ratio from the population in each arena ($t = 3.56$, df = 9, $P = 0.006$). Trapper and V-M327 trap catches had similar nymphal ratios as that from the population (Trapper: $t = 1.39$, df = 8, $P = 0.20$; V-M327: $t = -0.53$, df = 7, $P = 0.61$). However, there were not significant differences in nymphal ratios among the three traps ($F = 2.10$; df = 11,15; $P = 0.09$).

The large nymph/nymph ratios from the first 2 d of trapping in the arena experiment were calculated. The trap catches beyond 2 d was not included because of the natural changes in large nymph/nymph ratios. Only those observations with at least 10 nymphs were used. The mean large nymph/nymph ratios in V-M330, Trapper, and V-M327 were 0.18 ± 0.03, 0.16 ± 0.04, and 0.14 ± 0.04, respectively. The large nymph/nymph ratio of the populations when released to the arenas was 0.33. The ratios from the trap catches were significantly lower than the ratio from the population in each arena (V-M330: $t = -5.21$, df = 9, $P < 0.001$; Trapper: $t = -4.23$, df = 9, $P = 0.002$; V-M327: $t = -3.96$, df = 7, $P = 0.006$). Thus, small nymphs were more likely trapped by sticky traps than large nymphs. This might be caused by differences in movement patterns and/or abilities to escape after contact with the glue area. More observations would be needed to determine the dominant factor influencing the bias of the trap catches. The other traps were not analyzed because they had less than five valid replicates.

The mean nymphal ratios of cockroaches in the kitchen experiment were calculated based on cumulative trap catches for each kitchen and location. Only those observations with at least 10 cumulative catches were included. Mean nymphal ratio from the jar traps were 0.29 ± 0.06 ($n = 8$), whereas the mean ratios from the sticky traps ranged from 0.69 to 0.84. Compared with sticky traps, the jar trap catches had significantly lower nymphal ratios ($F = 17.2$; df = 7,43; $P < 0.001$). Similarly, Owens and Bennett (1983) found that the baby food jar trap was significantly biased for sampling adults compared with Mr. Sticky glue board traps. Robinson et al. (1980) sampled German cockroaches in apartments using 1-qt mason jars, with boiled raisins as an attractant and grease as a barrier. The nymphal ratio was only 28%. Apparently, the jar trap samples were biased toward adults because numerous studies using sticky traps or flushing and counting indicated the German cockroach nymphal ratios in urban residences were >74% (Ross and Mullins 1995). However, Owens and Bennett (1983) reported that the 1-qt mason jar trap designed at the University of California, Riverside, was not biased against German cockroach nymphs. Their traps used white bread as attractant and clay as barrier to prevent escape. The reasons for the differences between various jar trap designs remain to be studied.

Similar criteria were used for calculating the large nymph/nymph ratios in the kitchen experiment. The mean ratio from the jar trap catches was 0.48 ± 0.18 ($n = 5$), whereas the mean ratios from the sticky trap catches ranged from 0.05 to 0.11. C-150 was excluded from the analysis because there was only one valid observation. The large nymph/nymph ratio from the jar trap catches was significantly greater than those from the six sticky traps ($F = 7.4$; df = 6,36; $P < 0.001$). These data suggest that the catches from jar traps were positively correlated with the size (age) of the cockroaches.

The mean male/adult ratio of cockroaches in the kitchen experiment from the jar trap catches was 0.33 ± 0.03 ($n = 8$), whereas the mean ratios from the sticky trap catches ranged from 0.51 to 0.63. C-150 and C-2881 were excluded because there were less than four valid observations. The ratio from the jar trap catches was significantly lower than those from V-M327 and C-1001 (Tukey's test, $\alpha = 0.05$).

Comparative Effect of Attractants on Trap Catches in Simulated Kitchens. Because Trapper was the only trap without attractant or pheromone, we used it to study the effect of attractants on trap captures. Mixed model analysis (kitchen, location, and attractant as fixed effects, day as random effect) showed attractant had significant effect on trap catches ($F = 26.3$; df = 5,85; $P < 0.001$). All attractants significantly increased the trap catches compared with the untreated check (Dunnett's test, $\alpha = 0.05$). More cockroaches were caught in traps baited with bread and beer than any other attractant (Fig. 3; Tukey's test, $\alpha = 0.05$). Mean catches per 24 h in traps with bread and beer, Trapper roach attractant, Invite lure, NAF430, and peanut butter were 34-, 6-, 3-, 3-, and 2-fold, respectively, compared with the unbaited Trapper traps. There were no significant differences in the nymphal ratios (based on 2-d catches) among the baited traps ($F = 1.0$; df = 5,28; $P = 0.43$). Previous studies also found that bread was a very effective attractant for German cockroaches. Ebeling and Reierson (1974) reported that bread in-

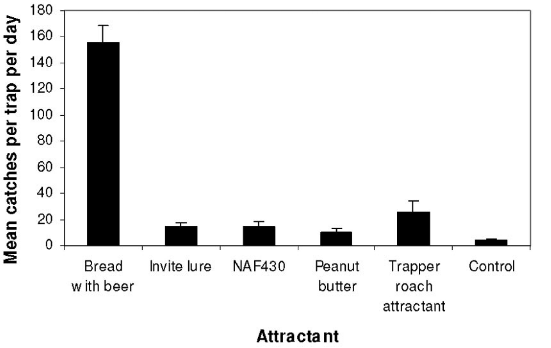

Fig. 3. Effect of attractants on trap catches (mean ± SEM) of the Trapper sticky traps placed in simulated kitchens ($n = 16$).

creased the jar trap catch by 7.6-fold. Ballard and Gold (1982) reported that white bread–baited sticky traps were 1.6 times more effective than the unbaited traps placed in infested apartments. Although most of the sticky traps used in this study contained attractants (Table 1), only V-M330 caught more cockroaches than the nonbaited Trapper traps. The pheromone or food scents used in the tested traps had limited effect compared with bread and beer. However, the bread and beer baits tend to become moldy or dry out quickly when left in open containers.

Identifying the key elements in the bait could be very beneficial for developing highly effective and convenient attractants and significantly increasing the efficacy of traps or toxic baits. Sticky traps were reported as not being able to effectively reduce German cockroach populations (Barak et al. 1977, Ballard and Gold 1983, 1984) because of a lack of attractiveness in commercially available traps. The high level of attractiveness of bread with beer shows promise for a greater role of sticky traps in controlling light cockroach infestations.

Effect of Trap Shape on Trap Catches. The mean catches of the flat and assembled (triangular) Trapper traps per day were 37 ± 3 and 21 ± 2, respectively ($n = 72$). Mixed model analysis (kitchen, location, and shape as fixed effects, day as random effect) showed flat Trapper traps were significantly more efficient than assembled Trapper traps ($F = 27.4$; df = 1,136; $P < 0.001$). The mean nymph/total ratios from the 3-d catches in the flat and assembled Trapper traps were 0.83 ± 0.02 and 0.66 ± 0.04, respectively ($n = 8$). The ratio from the flat traps was significantly greater than that from the assembled traps ($F = 14.0$; df = 1, 10; $P = 0.004$). Ballard and Gold (1984) found that flat Mr. Sticky traps were as efficacious as the assembled traps when placed in cockroach-infested apartments; however, the sample size was relatively small in that experiment.

In conclusion, results from this study indicate that there are significant differences among traps in the numbers of cockroaches they capture and the age bias in the cockroaches captured. Sticky traps are not suitable for controlling German cockroach infestations.

Small nymphs are more likely caught by sticky traps than large nymphs. Trap design such as surface around the glue area, shape (flat versus folded) can influence the effectiveness of the trap and age structure of the trapped cockroaches. The baby food jar trap is strongly biased for sampling adult cockroaches. It also has greater large nymph/nymph ratios and lower male/adult ratios than sticky traps. Attractants, especially bread with beer, can greatly increase sticky trap captures compared with unbaited sticky traps. The flat Trapper trap captured more cockroaches than the assembled Trapper trap, suggesting that flat traps can be used in narrow spaces such as under the shelf, refrigerator, or furniture. In combination with attractive bait, we expect that sticky traps may have the potential to remove significant numbers of cockroaches from an infested environment. With the concerns of cockroach insecticide resistance and excessive indoor pesticide use, baited sticky traps may play a bigger role in indoor cockroach management in the future.

Acknowledgments

We are grateful to B. Judt, M. Lanning, and A. Lane for technical assistance; B. Tyner and J. Xie for statistical advice; and Atlantic Past & Glue Co., Bell Laboratories, Rockwell Laboratories, Dow AgroSciences, and Woodstream for donating study materials. We thank G. Buczkowski and D. Richmond for reviewing an earlier draft of the manuscript. This is journal article no. 2005-17607 of the Agricultural Research Program of Purdue University, West Lafayette, IN.

References Cited

Appel, A. 1998. Daily pattern of trap-catch of German cockroaches (Dictyoptera: Blattellidae) in kitchens. J. Econ. Entomol. 91: 1136–1141.

Artyukhina, I. N. 1972. Methods of registration and criteria for evaluating the population density of *Blattella germanica* (L.). Med. Parazitol. Parazit. Bolezni. 41: 472–477.

Ballard, J. B., and R. E. Gold. 1982. The effect of selected baits on the efficacy of a sticky trap in the evaluation of German cockroach populations. J. Kans. Entomol. Soc. 55: 86–90.

Ballard, J. B., and R. E. Gold. 1983. Field evaluation of two trap designs used for control of German cockroach populations. J. Kan. Entomol. Soc. 56: 506–510.

Ballard, J. B., and R. E. Gold. 1984. Laboratory and field evaluations of German cockroach (Orthoptera: Blattellidae) traps. J. Econ. Entomol. 77: 661–665.

Barak, A. V., M. Shinkle, and W. E. Burkholder. 1977. Using attractant traps to help detect and control cockroaches. Pest Contr. 45: 14–16.

Ebeling, W., and D. A. Reierson. 1974. Bait trapping silverfish, cockroaches, and earwigs. Pest Contr. 42: 36–39.

Kaakeh, W., and G. W. Bennett. 1996. Evaluation of the Victor Roach Magnet traps (Laboratory testing, 1995). Arth. Mgt. Test. 21: 392.

Kaakeh, W., and G. W. Bennett. 1997. Evaluation of trapping and vacuuming compared with low-impact insecticide tactics for managing German cockroaches in residences. J. Econ. Entomol. 90: 976–982.

Kardatzke, J. T., I. E. Rhoderick, and J. H. Nelson. 1981. How roach surveillance saves time, material, and labor. Pest Contr. 49: 46–47.

Moore, W. S., and T. A. Granovsky. 1983. Laboratory comparisons of sticky traps to detect and control five species of cockroaches (Orthoptera: Blattidae and Blatellidae). J. Econ. Entomol. 76: 845–849.

Nalyanya, G., and C. Schal. 2001. Evaluation of attractants for monitoring populations of the German cockroach (Dictyoptera: Blattellidae). J. Econ. Entomol. 94: 208–214.

Owens, J. M. 1995. Detection and monitoring, pp. 93–108. *In* M. K. Rust, J. M. Owens, and D. A. Reierson (eds.), Understanding and controlling the German cockroach. Oxford University Press, New York.

Owens, J. M., and G. W. Bennett. 1983. Comparative study of German cockroach (Dictyoptera: Blattellidae) population sampling techniques. Environ. Entomol. 12: 1040–1046.

Piper, G. L., R. R. Fleet, G. W. Frankie, and R. E. Frisbie. 1975. Controlling cockroaches without synthetic organic insecticides. Texas A & M University, College Station, TX.

Reierson, D. A., and M. K. Rust. 1977. Trapping, flushing, counting German roaches. Pest Contr. 45: 42–44.

Robinson, W. H., R. C. Akers, and P. K. Powell. 1980. German cockroaches in urban apartment buildings. Pest Contr. 48: 18–20.

Ross, M. H., and D. E. Mullins. 1995. Biology, pp. 21–48. *In* M. K. Rust, J. M. Owens, and D. A. Reierson (eds.), Understanding and controlling the German cockroach. Oxford University Press, New York.

Rust, M. K., and D. A. Reierson. 1981. Attraction and performance of insecticidal baits for German cockroach control. Int. Pest Contr. 23: 106–109.

SAS Institute. 2001. User's manual, version 8.2. SAS Institute, Cary, NC.

Smith, L. M., and A. G. Appel. 2002. Comparison of several traps for catching German cockroaches (Dictyoptera: Blattellidae) under laboratory conditions, p. 451. *In* S. C. Jones, J. Zhai, and W. H. Robinson (eds.), Proceedings of the 4th International Conference on Urban Pests. Pocahontas Press, Blacksburg, VA.

Wang, C., and G. W. Bennett. 2004. Palatability and efficacy of a new gel bait for control of German cockroaches in a field setting, pp. 93–94. *In* T. Sutphin, D. Miler, and R. Kopanic (eds.), Proceedings of the 2004 National Conference on Urban Entomology. National Conference on Urban Entomology, Phoenix, AZ.

Received for publication 27 July 2005; accepted 22 March 2006.