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# The Response of German Cockroaches to Several Toxic Bait Formulations.

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## ABSTRACT

The response of the German cockroach, *Blattella germanica* (L.) to 9 consumer and 15 professional baits, with different active ingredients (chlorpyrifos, sulfluramid, hydramethylnon, abamectin, boric acid, propoxur, pyrethrins, and silicon dioxide) and formulations (gel, paste, loose granule, dust, solid in station) was determined in laboratory experiments. The bioassay design also considered the effects of alternate (competitive) food sources on each bait's performance. The role of bait brand, cockroach stage, and food or feeding bioassay (choice vs. no-choice) main effects on the mortality of cockroaches was determined. Comparison of the percentage of total experimental variations for percentage of mortality at 3, 7, and 14 d revealed that the bait brand explained more of the total experimental variation (81.2, 84.1, and 81.4% for consumer baits; and 89.5, 89.0, and 57.8% for professional baits, respectively) than stage and feeding bioassay main effects. Bait brands were not equally effective in killing the German cockroach. Differences between $LT_{50}$ and $LT_{95}$ values for bait brands in both feeding bioassays were significant. Based on $LT_{50}$s for consumer baits, Raid Max (chlorpyrifos) was the most accepted and the fastest working bait ($LT_{50}$ = 0.3 d) in both feeding bioassays; the least accepted and the slowest bait was Concern. The order of toxicity in the choice bioassay was Raid Max (chlorpyrifos) $<$ Pic boric acid $<$ Raid Max (sulfluramid) $<$ Victor powder < Raid ant bait plus < Combat < Roach Prufe < Knockdown < Concern. Most baits caused 100% mortality at the end of the 14-d test period and were significantly better than Concern in the no-choice bioassay and better than Combat, Knockdown, and Concern in the choice bioassay. Based on $LT_{50}$s for professional baits, Arthitrol formulations (granule and paste), Drione, and Strikeforce were the most acceptable and fastest-working baits in both feeding bioassays ($LT_{50}$ < 1d); the least accepted and the slowest active baits were the 4 boric acid bait formulations (Alpha 3, Drax Roach Kill, MRF 2000, and Niban-FG). Based on $LT_{50}$s, the order of toxicity in the choice bioassay was Arthitrol formulations < Drione < Strikeforce = Invader < Avert formulations < Maxforce formulations = Siege gel < Alpha 3 < Drax Roach Kill < MRF 2000 < Niban-FG. At the end of the 14-d test period, most baits caused 100% mortality and were significantly better than Drax Roach Kill, MRF 2000, and Niban-FG in both bioassays. Palatability ratios were highly variable. Ratios at $LT_{50}$ levels for most consumer and professional baits were significantly greater than 1.0, indicating a positive feeding deterrence. However, their magnitude is small and the values may well be explained purely by random feeding.

**Key words:** Bait, *Blattella germanica*, Blattellidae, Dictyoptera, oral toxicity.

## INTRODUCTION

German cockroaches, Blattella germanica (L.), are the most important domiciliary insect pest worldwide, and occurs in homes, apartments, and in commercial food-preparation and storage areas (Ebeling, 1978). Control of infestations by this pests relies on the timely and thorough application of a variety of residual insecticides (Rust, 1986). New technologies in cockroach baits and baiting strategies have made some baits (gel, paste, granule, dust, or in protective trays) as effective as residual insecticide formulations in controlling the German cockroach (Appel 1990, 1992, Kaakeh and Bennett 1996, 1997). The development of these technologies has been essential to pest control specialists in their quest to provide essential services in urban and industrial areas in an environmentally sensitive manner.

Laboratory and field performances of several consumer (over-the-counter) and professional (commercial) baits and dusts against the German cockroach have been reported (Milio et al. 1986, Rust 1986, Silverman and Shapas 1986, Reid et al. 1990, Koehler and Patterson 1991, Koehler et al. 1991, Appel 1990, 1992, Kaakeh et al. 1994a, 1994b, Appel and Benson 1995, Kaakeh and Bennett 1996, Kaakeh et al. 1996, Kaakeh and Bennett 1997, Kaakeh et al. 1997). Improvements in the toxicant, bait matrix, and application methods have made baits a reliable control strategy (Rust et al. 1983). Most consumer baits are contained in special trays or stations that can be applied mainly in the kitchen and bathroom. Bait stations offer easy application, precise placement, and relative safety (Appel 1992, Ogg and Gold 1993). Although bait stations are an effective application strategy, the number of stations needed to treat large commercial food preparation and storage facilities and scattered cockroach populations effectively may be prohibitive. Therefore, beside bait stations, professional bait baits consist of insecticidal gel, paste, or granule formulations. These can be applied into crack and crevice sites where they are protected from removal and easily inspected (Appel 1990).

The objective of this study was to determine the response of an insecticide-susceptible strain of the German cockroach to several commonly available consumer (over-the-counter) and professional (commercial) baits, in continuous-exposure toxicity tests,. Because bait formulations must be palatable and toxic in the amounts consumed (Appel 1992), our bioassay design also considered the effects of alternate (competitive) food sources on the performance of each bait.

## MATERIALS AND METHODS

### Test Insects:

Laboratory experiments were conducted at the Center for Urban and Industrial Pest Management at Purdue University in West Lafayette, Indiana (USA) in 1996 and 1997. Cultures of test insects were maintained at 26±2°C, 70±5% RH, and a photoperiod of 12 : 12 (L:D) h, and provided with an unlimited supply of water and a standard laboratory diet of Tekland # 8604 rodent blox (Harlan Teklad, Madison, WI). An insecticide-susceptible (JWax) strain of the German cockroach was used in this study. This strain was isolated from the field by S. C. Johnson and Sons, Inc. (Racine, WI), in the late 1930s, before the introduction of synthetic organic insecticides.

**Oral Toxicity:**

Plastic boxes (30 by 24 by 10 cm) (Tristate Plastic, Dixon, KY) occupying 720 $cm^2$ of floor area were used as test arenas. Tent harborage, positioned in the center of the arena, was fashioned from a piece (14 by 22 cm) of non-corrugated cardboard. Two water vials (25-ml glass, cotton-stoppered) were placed along the walls of the arena; 2 food dispensers (3.7-cm-diameter plastic weigh boats) were glued to the floor of the arena, and positioned in opposing corners. Water vials and dispensers resources were positioned to allow an unobstructed, 1-cm runway around the perimeter of the arena floor. Arenas were made escape-proof by use of ventilated, friction-fitted lids, and the application of an impassable barrier of petrolatum and mineral oil (1:2) to the arena walls. This barrier was applied to within 1 - 2 cm of the arena floor to prevent test insects from climbing the arena walls, and thereby confining all exploratory behaviors to the arena floor and the provisions of the arena.

The effect of alternate food sources on bait performance was also considered. The following basic pattern for the placement of the bait: no-choice, where patterns were placed in opposing corners of the arena; and, choice, where supplemental food sources (2 g each of rodent blox and grape jelly) were placed in the corners opposite the baits. Cockroaches in the control treatment were provided with rodent blox and water. The test population was composed of 30 cockroaches (10 newly eclosed [<48 h of eclosion] adult males, 10 newly eclosed virgin females, and 10 newly eclosed 4th instars). Sex was not determined in 4th instars. Cockroaches were released into the arenas and, after a 24-h acclimation period, baits were placed in the arenas. Cockroach mortality was observed at 24-h intervals for 14 d.

The response of the German cockroach to 9 consumer and 15 professional baits and dusts, containing various active ingredients (chlorpyrifos, sulfluramid, hydramethylnon, abamectin, boric acid, propoxur, pyrethrins, and silicon dioxide) and formulations (gel, paste, loose granule, dust, solid in bait station) was determined in this study (Table 1). Treatments (for each bait type and controls without bait) were replicated 3 times in a completely randomized design. Percentage of cockroach mortality was analyzed with analysis of variance (ANOVA) models to characterize the significance of the differing baiting schemes (choice versus no-choice). Means were separated by Duncan's multiple range test ($P < 0.05$; SAS Institute 1990). Daily percentage of cockroach mortality was corrected for control mortality using Abbott's (1925) formula. The lethal time (LT) for each bait and feeding bioassay treatment was determined by probit analysis of daily, cumulative mortality (SAS Institute 1990). Using the LTx values from the probit analyses, palatability ratios were calculated for each bait using the formula PRx = LTx (choice)/LTx (no choice). The confidence interval (± 95% CL) about the palatability ratio was calculated after the method of Robertson and Preisler (1992). Failure of the 95% CI of LT50s to overlap was used to indicate significant difference ($P < 0.05$).

## RESULTS AND DISCUSSION

The overall results for 3-factor ANOVA model (Table 2), for the percentage of mortality, were highly significant ($P < 0.01$) at 3, 7, and 14 d after baiting for both consumer and professional baits. Stage main effect for consumer baits was significant ($P < 0.05$) at day 7. Bait brand, followed by food and stage, was the most significant main effect in the model. Comparison of the percentage of total experimental variations for percentage of mortality at 3, 7, and 14 d revealed that bait brand (for both consumer and professional baits) explained more of the total experimental variation (81.2, 84.1, and 81.4% for consumer baits; and 89.5, 89.0, and 57.8% for professional baits, respectively) than the other main effects. Stage and food described less, but significant, experimental variation (range: 0.2–5.0 during the test period) than did bait brand. In general, feeding patterns of males and nymphs differ markedly (DeMark et al. 1993), but the bait active ingredient may affect each stage differently (Reierson, 1995). This may be related to size differences, metabolism and physiology. Koehler et al. (1993) and Valles et al. (1996) also have shown that large *B. germanica* nymphs are considerably more tolerant of insecticides than adult males (i.e., stage-dependent effect). The mechanism responsible for this phenomenon was due to enhanced detoxification (Valles et al. 1996). These variable results showed that differences in cockroach mortality by different brands, for each bait type, had more effect on the experimental variation than did the other main effects.

Comparing the percentage of the total experimental variations on selected days after baiting revealed that some interactions explained more of the total experimental variation than did the stage and food main effects (e.g., bait brand × stage and bait brand × food for both bait types) with one exception (bait brand × stage at day 7 for consumer baits).

Bait brands were not equally effective in killing *B. germanica.* Differences between $LT_{50}$ and $LT_{95}$ values for brands in both feeding bioassays (choice versus no-choice) were significant (i.e., no overlap in 95% CL values [Table 3]). Comparison of $LT_{50}$s for consumer baits indicated that Raid Max (chlorpyrifos) was the most accepted and the fastest working bait ($LT_{50}$ = 0.3 d) in both feeding bioassays; the least accepted and the slowest bait was Concern ($LT_{50}$ = 14.8 d in the nochoice bioassay and 526.6 d in the choice bioassay). Based on LT50s, the order of toxicity of these bait brands in the no-choice bioassay was Raid Max (chlorpyrifos) < Raid Max (sulfluramid) < Knockdown < Pic boric acid < Victor powder < Combat < Raid ant bait plus < Roach Prufe < Concern. The order of toxicity in the choice bioassay was Raid Max (chlorpyrifos) < Pic boric acid < Raid Max (sulfluramid) < Victor powder < Raid ant bait plus < Combat < Roach Prufe < Knockdown < Concern. At the end of the 14-d test period, all bait brands in the nochoice bioassay caused 100% mortality and were significantly better than Concern (40% mortality). In the choice test, all bait brands caused

100% mortality and were significantly better than Combat (93%), Knockdown (86%), and Concern (2%) in the choice bioassay.

The $LT_{50}$ of Raid Max (chlorpyrifos) in this study (0.3 d in the choice bioassay) was similar to that reported by Appel (1990). The $LT_{50}$ of Combat (6.7 d in the choice bioiassay) was much longer than that found by Appel (1990) with $LT_{50}$ = 0.9 d. Faster mortality would be expected in the Appel (1990) bioassay for 2 reasons: (1) because only males were used in the test, and (2) the toxic tablet was removed from the Combat bait station and placed beside the food in a small testing arena (i.e., 1 liter glass jar).

Comparison of $LT_{50}$s for the professional baits indicated that Arthitrol formulations (granule and paste), Strikeforce, and Drione were the most acceptable and fastest-working brands in both feeding bioassays ($LT_{50}$ < 1d); the least accepted and the slowest brands were the boric acid baits (Alpha 3, Drax Roach Kill, MRF 2000, and Niban-FG). Based on $LT_{50}$s, the order of toxicity of these brands in the no-choice bioassay was the Arthitrol < Drione < Strikeforce = Invader < Avert Bait < Avert PT300 = Avert PT310 = Maxforce Gel < Maxforce Bait = Siege Gel < Alpha 3 = Drax Roach Kill < MRF 2000 < Niban-FG. The order of toxicity in the choice bioassay was Arthitrol formulations < Drione < Strikeforce = Invader < Avert formulations < Maxforce formulations = Siege gel < Alpha 3 < Drax Roach Kill < MRF 2000 < Niban-FG. At the end of the 14-d test period, most brands caused 100% mortality and were significantly better than Drax Roach Kill (91%), MRF 2000 (89%) and Niban-FG (90%) in the nochoice bioassay and better than Drax Roach Kill (76%), MRF 2000 (76%) and Niban-FG (11%). Control mortality was 2, 6, and 7% at 3, 7, and 14 d after baiting, respectively.

$LT_{50}$s of Avert baits against mixed-stage cockroaches were similar in both feeding bioassays (Table 3) and were smaller than those reported by Appel and Benson (1995). Dry formulations had lower LT50s than water-containing formulations for adult males. The $LT_{50}$ of Avert PT310 in the choice bioassay (2.6 d) was similar to that reported by Appel and Benson (1995) from the glass jar bioassay, but was slightly less than the $LT_{50}$ obtained from the Ebeling choice box bioassay (4.1 d). The $LT_{50}$ for Avert PT300 was much less than those reported by Appel and Benson (1995). This is due to the use of different methods to evaluate the bait (i.e., the use Ebeling choice box or glass jar bioassays instead of the sweater box in our study). The $LT_{50}$ of Maxforce gel in the choice bioassay in this study (3.1 d) was similar to those reported by Appel (1990) in the Ebeling choice box (2.4 d) and a continuous exposure bioassay (jar with harborage; 4.2 d).

Based on the active ingredient, the overall toxicity ranking of the consumer baits, 3 d after baiting (Table 3), was chlorpyrifos = sulfluramid > boric acid = hydramethylnon > silicon dioxide. The overall toxicity ranking of the professional baits was chlorpyrifos = silica gel > abamectin > hydramethylnon > boric acid.

Analysis of palatability revealed the effect of alternate foods on lethal time values; if the bait formulation displays any non-palatable qualities, the lethal time will be slowed in the choice bioassay relative to the no-choice bioassay. If the resulting 95% CL encompass 1.0, there is no significant change to the efficacy of the bait and minimal interference to the bait caused by the presence of an alternative food source. If the 95% CL does not encompass 1.0, there is interference with efficacy of the bait caused by the presence of alternate food. Palatability ratios were highly variable in this study (Table 4). At the $LT_{50}$ levels, the $PR_{50}$ values for most consumer and professional baits were significantly greater than 1.0; this may indicate a positive feeding deterrence. However, their magnitude is small and the values may well be explained purely by random feeding. The PR50s for consumer baits ranged from 0.0 to 2.1 (3.1 for Knockdown and 35.8 for Concern) and PR95s ranged from 0.9 to 4.2 (351.7 for Concern). The PR50s of the tested baits ranged from 0.9 to 2.1 d for consumer baits and from 1.1 to 2.0 d for professional baits (with few exceptions). The PR95s ranged from 0.9 to 4.2 d for consumer baits and from 0.9 to 2.2 d for professional baits (with few exceptions). If the extreme PR50 and PR95 values for Concern and

Niban-FG result from feeding deterrance, it cannot be established quantitatively; however, this possibility is strongly indicated.

The palatability of the bait base and the incorporation of an insecticide with minimal repellency (lacking feeding deterrence) are needed for an effective bait because the attraction of the food must not change in the presence of the insecticide. Various parameters have been shown to influence the palatability of the bait, including bait texture (Appel and Benson 1995), food quality (Appel 1990), water content (Appel 1992, Appel and Benson 1995), deposition of repellent compound (e.g., grease and mold) on the bait, and repellency of bait toxicant (Reierson and Rust 1984, Appel 1990, 1992, Appel and Benson 1995). Selection of an appropriate bait formulation (gel, paste, granule, solid in a bait station) for the conditions of a particular infestation may further increase bait performance (Appel and Benson 1995).

Our results indicated that *B. germanica* showed differential susceptibility to a variety of formulated baits. However, because bait performance in the field does not always correlate well with results obtained in the laboratory (Rust and Reierson 1981, Appel 1990), field testing of the baits reported in this study will provide information on other parameters affecting their performance. This may lead to the improvement in the performance, design, and dispensing of baits for the control of German cockroaches.

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## REFERENCES

Abbott, W. S. 1925. A method for computing the effectiveness of an insecticide. J. Econ. Entomol. 18: 265-267.

Appel, A. G. 1990. Laboratory and field performance of consumer bait baits for German cockroach (Dictyoptera: Blattellidae) control. J. Econ. Entomol. 83: 153–159.

Appel, A. G. 1992. Performance of gel and paste bait baits for German cockroach (Dictyoptera: Blattellidae) control: laboratory and field studies. J. Econ. Entomol. 85: 1176–1183.

Appel, A. G. and E. P. Benson. 1995. Performance of abamectin bait formulations against German cockroaches (Dictyoptera: Blattellidae). J. Econ. Entomol. 88: 924–931.

DeMark, J.J ., T. Kuczek and G. W. Bennett. 1993. Laboratory analysis of the foraging efficiency of nymphal German cockroaches (Dictyoptera: Blattellidae) between resource sites in an experimental arena. Ann. Entomol. Soc. Am. 86: 372–378.

Ebeling, W. 1978. Urban entomology. University of California, Division of Agricultural Sciences, Berkeley.

Kaakeh, W., M. E. Scharf, B. L. Reid and G. W. Bennett. 1994a. Field trials of cockroach baits, 1992-1993. Arthropod Management Tests 19: 355.

Kaakeh, W., B. L. Reid and G. W. Bennett. 1994b. Speed of action in cockroach bait, 1993. Arthropod Management Tests 19: 361–362.

Kaakeh, W. and G. W. Bennett. 1996. Speed of action in Siege and Maxforce gel baits, 1995. Arthropod Management Tests 21: 391–392.

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.

Kaakeh, W., B. L. Reid and G. W. Bennett. 1996. Horizontal transmission of the entomopathogenic fungus, Metarhizium anisopliae, (Imperfect Fungi: Hyphomycetes) and hydramethylnon among German cockroaches (Dictyoptera: Blattellidae). J. Entomol. Sci. 31: 378-390.

Kaakeh, W., B. L. Reid and G. W. Bennett. 1997. Toxicity of fipronil to German and American cockroaches. Entomol. Exp. Appl. 84: 229-237.

Koehler, P. G., and R. S. Patterson. 1991. Toxicity of hydramethylnon to laboratory and field strains of German cockroach (Orthoptera: Blattellidae). Florida Entomol. 74: 345–349.

Koehler, P. G., T. H. Atkinson, and R. S. Patterson. 1991. Toxicity of abamectin to cockroaches (Dictyoptera: Blattellidae, Blattidae). J. Econ. Entomol. 84: 1758–1762.

Koehler, P. G. , C. A. Strong, R. S. Patterson and S. M. Valles. 1993. Differential susceptibility of German cockroach (Dictyoptera: Blattellidae) sexes and nymphal age classes to insecticides. J. Econ. Entomol. 86: 785–790.

Milio, J. F., P. G. Koehler and R. S. Patterson. 1986. Laboratory and field evaluations of hydramethylnon bait formulations for control of American and German cockroaches (Orthoptera: Blattellidae). J. Econ. Entomol. 79: 1280–1286.

Ogg, C. L. and R. E. Gold. 1993. Inclusion of insecticidal bait stations in a German cockroach (Orthoptera: Blattellidae) control program. J. Econ. Entomol. 86: 61–65.

Reid, B. L., G. W. Bennett and S. J. Barcay. 1990. Topical and oral toxicity of sulfluramid, a delayed-action insecticide, against the German cockroach (Dictyoptera: Blattellidae). J. Econ. Entomol. 83: 148–152.

Reierson, D. A. and M. K. Rust. 1984. Insecticidal baits and repellency in relation to control of the German cockroach, *Blattella germanica* (L.). Pest Manag. 2: 26–32.

Reireson, D. A. 1995. Baits for German cockroach control, pp. 231-265. *In* M. K. Rust, J. M. Owens and D. A. Reierson [eds.], Understanding and controlling the German cockroach. Oxford Press, New York.

Robertson, J. L. and H. K. Preisler. 1992. Pesticide bioassay with arthropods. CRC, Boca Raton, FL.

Rust, M. K. 1986. Managing household pests. In: G. W. Bennett and J. M. Owens [Eds.], pp. 335–368. 'Advances in urban pest management'. Van Nostrand Reinhold, New York.

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

Rust, M. K., D. A. Reierson, and A. M. Van Dyke. 1983. Performance of insecticides for German cockroach in apartments. Insecticide and Acaricide Tests 8: 55.

SAS Institute. 1990. SAS user's guide: statistics version 6. SAS Institute, Gary, NC.

Silverman, J. and T. J. Shapas. 1986. Cumulative toxicity and delayed temperature effects of hydramethylnon on German cockroaches (Orthoptera: Blattellidae). J. Econ. Entomol. 79: 1613–1616.

Valles, S. M., S. J. Yu and & P. G. Koehler, 1996. Biochemical mechanisms responsible for stage-dependent propoxur tolerance in the German cockroach. Pest. Biochem. Physiol. 54: 172–180.

Table 1. Consumer and professional baits used for the control of the German cockroach

| Bait | Bait Brand | Active Ingredients | % AI | Formulation | EPA Reg. No. | Manufacturer (Address) |
|---|---|---|---|---|---|---|
| Consumer | Raid Max | Sulfluramid | 1 | Station | 1812-329-4822 | SC Johnson & Son (Racine, WI) |
| | Raid Ant Baits Plus | Sulfluramid | 0.5 | Station | 4822-356 | SC Johnson & Son (Racine, WI) |
| | Raid Max Roach Bait | Chlorpyrifos | 0.528 | Station | 4822-411 | SC Johnson & Son (Racine, WI) |
| | Combat Roach Killing | Hydramethylnon | 1 | Station | 64240-4 | Clorox (Pleasanton, CA) |
| | Victor Roach Killing | Boric Acid | 100 | Powder | 51311-1-47629 | Woodstream (Lititz, PA) |
| | Pic Boric Acid | Boric Acid | 99 | Powder | 3095-20201 | Pic Corporation (Orange, NJ) |
| | Roach Prufe | Boric Acid | 99 | Powder | 9608-2 | Copper Brite (Santa Barbara, CA) |
| | Knockdown | Boric Acid | 47 | Station | 47629-2 | Woodstream (Lititz, PA) |
| | | GC Pheromone | 0.004 | | | |
| | Concern[a] | Silicon Dioxide | 85 | Dust | 59910-1-50932 | Necessary Organics (New Castle, VA) |
| | | Other elemental oxides | 10 | | | |
| Professional | Arthitrol G | Chlorpyrifos | 0.5 | Granular | 11649-17 | Avitrol (Tulsa, OK) |
| | Arthitrol P | Chlorpyrifos | 0.5 | Paste | 69159-2 | Avitrol (Tulsa, OK) |
| | Strikeforce | Chlorpyrifos | 0.5 | Station | 3095-64-9444 | Waterbury (Waterbury, CT) |
| | Maxforce Gel | Hydramethylnon | 2.15 | Gel | 64248-5 | Clorox (Pleasanton, CA) |
| | Siege | Hydramethylnon | 2 | Gel | 241-313 | American Cyanamid (Wayne, NJ) |
| | Maxforce Bait | Hydramethylnon | 2 | Station | 64248-1 | Clorox (Pleasanton, CA) |
| | Avert PT 310 | Abamectin | 0.05 | Powder | 499-294 | Whitmire Res. Lab. (St. Louis, MO) |
| | | Related compounds | 0.04 | | | |

| | | | | | |
|---|---|---|---|---|---|
| Avert PT 300 | Abamectin | 0.01 | Press. Bait | 499-294 | Whitmire Res. Lab. (St. Louis, MO) |
| Avert Bait | Abamectin | 0.05 | Station | 499-467 | WACO Chemical (Hyden, KY) |
| Alpha 3 | Boric Acid | 33.3 | Paste | 65700-1 | Whitmire Res. Lab. (St. Louis, MO) |
| Drax Roach Kill | Boric Acid | 33.3 | Gel | 3095-68-9444 | Waterbury (Waterbury, CT) |
| M.R.F. 2000 | Boric Acid | 33.3 | Paste | 54452-2 | Blue Diamond (Mooresburg, TN) |
| Niban-FG | Boric Acid | 5 | Granular | 64405-2 | Nisus Corporation (Rockford, TN) |
| Drione[a] | Amorphous Silica Gel | 40 | Dust | 4816-353AA | AgrEvo (Montvale, NJ) |
| | Technical PBO | 10 | | | |
| | Pyrethrins | 1 | | | |
| Invader | Propoxur | 2 | Station | 3095-25-9444 | Waterbury (Waterbury, CT) |

[a] Concern and Drione are dusts.

Table 2. Full-Model ANOVA (with product, stage, and feeding bioassay [food] as the main effects) for the percentage of B. *germanica* mortality caused by baits used by consumers and professionals

| | | | % mortality at selected times (d) after baiting | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 3 d | | | 7 d | | | 14 d | | |
| Bait | Source | df | F | $P^a$ | %TEV[b] | F | P | %TEV | F | P | %TEV |
| Consumer | Bait Brand (BB) | 8 | 141.1 | ** | 81.2 | 91.9 | ** | 84.1 | 456.5 | ** | 81.4 |
| | Stage | 2 | 5.8 | ** | 0.8 | 4.6 | * | 1.0 | 24.2 | ** | 0.9 |
| | BB x Stage | 16 | 2.2 | ** | 2.4 | 0.4 | ns | 0.7 | 18.5 | ** | 5.5 |
| | Food | 1 | 46.2 | ** | 3.3 | 37.2 | ** | 4.2 | 78.0 | ** | 1.5 |
| | BB x Food | 8 | 19.2 | ** | 11.1 | 9.4 | ** | 2.9 | 32.8 | ** | 4.9 |
| | Stage x Food | 2 | 0.3 | ns | 0.03 | 0.04 | ns | 0.01 | 12.9 | ** | 0.8 |
| | BB x Stage x Food | 16 | 1.0 | ns | 1.1 | 0.7 | ns | 1.3 | 18.4 | ** | 5.5 |
| Professional | Bait Brand (BB) | 14 | 153.4 | ** | 89.5 | 257.4 | ** | 89.0 | 124.2 | ** | 57.8 |
| | Stage | 2 | 23.3 | ** | 1.9 | 22.5 | ** | 1.1 | 3.7 | * | 0.2 |
| | BB x Stage | 28 | 3.2 | ** | 3.7 | 5.4 | ** | 3.7 | 2.2 | ** | 2.1 |
| | Food | 1 | 38.4 | ** | 1.6 | 44.4 | ** | 1.1 | 151.0 | ** | 5.0 |
| | BB x Food | 14 | 2.8 | ** | 1.7 | 9.8 | ** | 3.4 | 70.2 | ** | 32.7 |
| | Stage x Food | 2 | 1.6 | ns | 0.1 | 0.9 | ns | 0.05 | 1.5 | ns | 0.1 |
| | BB x Stage x Food | 28 | 1.2 | ns | 1.4 | 2.4 | ** | 1.7 | 2.2 | ** | 2.0 |

[a] ns, *, and ** indicate non-significance and significance at the 5 and 1% levels, respectively.
[b] %TEV, percentage of total experimental variation = (source sum of square/model sum of square) x 100.

Table 3. Lethal times ($LT_{50}$ and $LT_{95}$) and percentage of German cockroach mortality for consumer and professional baits in each feeding bioassay (choice and nochoice).

| Bait | Alternate Food | Bait brand | Formulation | n[a] | $X^{2b}$ | Slope ± SE | $LT_{50}$ (95% CI.)[c] | $LT_{95}$ (95% CI.)[c] | % mortality at day[d] 3 | 7 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Consumer | No-choice | Raid (sulfluramid) | station | 270 | 3.4* | 5.6 ± 1.1 | 1.3 (–) | 2.5 (–) | 100 a | 100 a | 100 a |
| | | Raid (chlorpyrifos) | station | 360 | 2.0 | 2.2 ± 0.6 | 0.3 (0.0–0.5) | 1.7 (1.3–2.4) | 99 a | 100 a | 100 a |
| | | Pic Boric Acid | powder | 540 | 8.8* | 9.8 ± 1.2 | 2.9 (2.6–3.2) | 4.3 (3.8–5.2) | 63 b | 100 a | 100 a |
| | | Combat | station | 900 | 19.8* | 5.2 ± 0.5 | 3.8 (3.3–4.1) | 7.7 (6.8–9.2) | 32 c | 91 ab | 100 a |
| | | Victor | powder | 810 | 39.3* | 4.6 ± 0.7 | 3.6 (3.0–4.3) | 8.3 (6.7–12.3) | 22 cd | 91 ab | 100 a |
| | | Raid Ant Bait | station | 900 | 37.0* | 5.0 ± 0.6 | 3.9 (3.3–4.5) | 8.4 (7.0–11.0) | 18 cd | 87 b | 100 a |
| | | Roach Prufe | powder | 990 | 71.0* | 3.6 ± 0.5 | 6.1 (4.9–7.5) | 17.5 (12.4–36.9) | 11 de | 50 c | 100 a |
| | | Knockdown | station | 450 | 27.4* | 5.3 ± 1.2 | 2.4 (1.3–3.5) | 4.9 (3.4–33.6) | 59 b | 100 a | 100 a |
| | | Concern | dust | 1260 | 13.9 | 4.1 ± 0.4 | 14.8 (13.6–16.4) | 37.4 (30.4–50.3) | 0 e | 8 d | 40 b |
| | | *F* | | | | | | | 54.8 | 75.3 | 17.3 |
| | | *P* | | | | | | | <0.01 | <0.01 | <0.01 |
| | Choice | Raid (sulfluramid) | station | 630 | 8.4 | 4.8 ± 0.3 | 2.7 (2.5–2.9) | 5.9 (5.4–6.7) | 47 c | 100 a | 100 a |
| | | Raid (chlorpyrifos) | station | 270 | 1.2 | 2.6 ± 0.9 | 0.3 (0.0–0.6) | 1.4 (1.1–2.1) | 100 a | 100 a | 100 a |
| | | Pic Boric Acid | powder | 450 | 18.2* | 8.1 ± 1.7 | 2.5 (1.7–3.1) | 3.9 (3.1–9.3) | 81 b | 100 a | 100 a |
| | | Combat | station | 1260 | 12.6 | 3.6 ± 0.2 | 6.7 (6.4–7.1) | 19.1 (17.2–21.7) | 8 e | 53 c | 93 b |
| | | Victor | powder | 900 | 36.7* | 4.6 ± 0.6 | 3.3 (2.8–3.9) | 7.6 (6.3–10.1) | 27 d | 94 a | 100 a |
| | | Raid Ant Bait | station | 990 | 8.3 | 6.2 ± 0.4 | 4.9 (4.7–5.1) | 9.1 (8.5–9.8) | 11 e | 77 b | 100 a |
| | | Roach Prufe | powder | 1260 | 639.2* | 4.2 ± 1.6 | 7.1 (3.4–12.6) | 17.7 (10.8–796.2) | 8 e | 34 d | 100 a |
| | | Knockdown | station | 1260 | 19.6* | 3.7 ± 0.3 | 7.3 (6.8–7.8) | 20.5 (17.6–25.0) | 3 e | 43 cd | 86 c |
| | | Concern | dust | 1260 | 3.6 | 1.2 ± 0.5 | 526.6 (85.1–>1000) | 13023.0 (515.5–>15000) | 0 e | 2 e | 2 d |
| | | *F* | | | | | | | 90.4 | 44.1 | 306.6 |
| | | *P* | | | | | | | <0.01 | <0.01 | <0.01 |

| Bait | Alternate Food | Bait brand | Formulation | n[a] | $X^{2b}$ | Slope ± SE | $LT_{50}$ (95% CI.)[c] | $LT_{95}$ (95% CI.)[c] | % mortality at day[d] 3 | 7 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Professional | No-choice | Arthitrol G | granules | 90 | -** | - | -* | -* | 100 a | 100 a | 100 a |
| | | Arthitrol P | paste | 90 | -** | - | -* | -* | 100 a | 100 a | 100 a |
| | | Drione | dust | 270 | 0.4 | 2.1 ± 1.3 | 0.1 (–) | 0.8 (–) | 100 a | 100 a | 100 a |
| | | Strikeforce | station | 360 | 1.8 | 1.8 ± 0.6 | 0.2 (0.0–0.5) | 1.7 (1.2–2.6) | 98 a | 100 a | 100 a |
| | | Invader | station | 540 | 7.5 | 1.5 ± 0.3 | 0.4 (0.1–0.6) | 4.9 (3.7–8.2) | 87 ab | 100 a | 100 a |
| | | Avert Bait | station | 720 | 8.7 | 2.4 ± 0.2 | 1.2 (1.0–1.4) | 6.0 (5.1–7.4) | 78 b | 99 a | 100 a |
| | | Avert PT 300 | press. bait | 630 | 8.6 | 4.8 ± 0.3 | 2.0 (1.9–2.2) | 4.4 (4.0–5.0) | 79 b | 100 a | 100 a |
| | | Avert PT 310 | powder | 630 | 11.4* | 3.9 ± 0.4 | 2.1 (1.7–2.4) | 5.5 (4.5–7.5) | 61 c | 100 a | 100 a |
| | | Maxforce Gel | gel | 630 | 7.3 | 5.3 ± 0.4 | 2.0 (1.8–2.1) | 4.0 (3.7–4.5) | 83 b | 100 a | 100 a |
| | | Maxforce Bait | station | 540 | 42.0* | 13.6 ± 4.0 | 3.3 (2.4–4.2) | 4.4 (3.7–14.3) | 16 e | 100 a | 100 a |
| | | Siege | gel | 540 | 6.5 | 6.9 ± 0.5 | 3.0 (2.8–3.1) | 5.1 (4.8–5.7) | 48 cd | 100 a | 100 a |
| | | Alpha 3 | paste | 1260 | 15.0 | 3.7 ± 0.2 | 3.9 (3.7–4.2) | 10.8 (10.0–11.9) | 34 d | 80 b | 100 a |
| | | Drax Roach Kill | gel | 1260 | 24.7* | 2.7 ± 0.2 | 4.4 (3.9–5.0) | 18.2 (15.0–23.6) | 34 d | 73 b | 91 b |
| | | M.R.F. 2000 | paste | 1260 | 3.9 | 3.2 ± 0.2 | 6.1 (5.7–6.4) | 19.4 (17.3–22.3) | 17 e | 60 c | 89 b |
| | | Niban-FG | granule | 1260 | 7620.3* | 4.6 ± 7.2 | 10.4 (0.0–0.0) | 23.6 (0.0–0.0) | 1 f | 17 d | 90 b |
| | | *F* | | | | | | | 50.4 | 52.7 | 4.1 |
| | | *P* | | | | | | | <0.01 | <0.01 | <0.01 |
| | Choice | Arthitrol G | granules | 90 | -** | - | -* | -* | 100 a | 100 a | 100 a |
| | | Arthitrol P | paste | 90 | -** | - | -* | -* | 100 a | 100 a | 100 a |
| | | Drione | dust | 450 | 7.2* | 1.7 ± 0.5 | 0.4 (-) | 4.3 (-) | 90 a | 100 a | 100 a |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Strikeforce | station | 450 | 1.3 | 2.1 ± 0.4 | 0.3 (0.1 - 0.6) | 2.1 (1.7 - 2.9) | 97 a | 100 a | 100 a |
| Invader | station | 630 | 19.2* | 1.8 ± 0.5 | 0.8 (0.1 - 1.4) | 6.2 (3.8 - 31.8) | 75 b | 100 a | 100 a |
| Avert Bait | station | 810 | 8.1 | 3.8 ± 0.2 | 2.1 (1.9 - 2.3) | 5.6 (5.1 - 6.4) | 76 b | 99 a | 100 a |
| Avert PT 310 | powder | 630 | 13.7* | 4.7 ± 0.5 | 2.6 (2.2 - 3.0) | 5.9 (4.9 - 8.0) | 48 c | 100 a | 100 a |
| Avert PT 300 | press. bait | 720 | 4.3 | 4.8 ± 0.3 | 2.4 (2.3 - 2.6) | 5.4 (4.9 - 6.0) | 69 b | 99 a | 100 a |
| Maxforce gel | gel | 900 | 7.4 | 3.5 ± 0.2 | 3.1 (2.8 - 3.3) | 9.0 (8.1 - 10.1) | 49 c | 88 b | 100 a |
| Maxforce Bait | station | 540 | 1.1 | 12.2 ± 1.1 | 3.6 (3.5 - 3.7) | 4.9 (4.7 - 5.2) | 17 de | 100 a | 100 a |
| Siege | gel | 630 | 32.5 | 4.8 ± 0.9 | 3.7 (2.9 - 4.5) | 8.1 (6.1 - 16.4) | 38 c | 100 a | 100 a |
| Alpha 3 | paste | 1260 | 18.7* | 3.1 ± 0.2 | 4.3 (3.9 - 4.8) | 14.9 (12.9 - 17.8) | 23 d | 78 c | 96 a |
| Drax Roach Kill | gel | 1260 | 9.6 | 2.6 ± 0.2 | 7.9 (7.4 - 8.5) | 34.1 (28.4 - 43.2) | 14 def | 39 d | 76 b |
| M.R.F. 2000 | paste | 1260 | 5.0 | 3.4 ± 0.2 | 9.4 (8.9 - 10.0) | 28.3 (24.4 - 34.2) | 3 ef | 38 d | 70 c |
| Niban-FG | granule | 1260 | 7.8 | 1.3 ± 0.3 | 197.7 (67.7 - >100) | 3671 (473.5 - >1000) | 1 f | 2 e | 11 d |
| *F* | | | | | | | 55.7 | 91.5 | 156.4 |
| *P* | | | | | | | <0.01 | <0.01 | <0.01 |

Means in the same column followed by the same letters are not significantly different (LSD test; $P < 0.05$; SAS Institute 1990).

[a]Number of observations (time intervals x number of insects) included in the regression analysis from which $LT_{50}$ and $LT_{95}$ were calculated.

[b] Because the chi-square is small ($P$>0.1), confidence limits were calculated using a $t$ value of 1.96. The large chi-square (indicated by an asterisk) is not caused by systematic departure from the model; a $t$ value of 2.11 was used in computing confidence limits. The ** indicates zero degree of freedom for the Goodness-of-fit tests.

[c]Number of days before death of 50 or 95% of the test population following exposure to toxic baits. In some instances, the use of a large $t$ value caused a non-realistic confidence interval to be calculated. The $LT_{50}$ or $LT_{95}$ with overlapping 95% CL are not significantly different. The * indicates that there was a single response value (i.e., 100% mortality at day 1); no LT estimates were done.

Table 4. Palatability of consumer and professional baits in mixed-age groups of a susceptible strain of German cockroaches.

| Bait | Bait Brand[a] | Palatability ratios PR50 (95%CL)[b] | PR95(95%CL)[b] |
|---|---|---|---|
| Consumer | Raid Max (sulfluramid) | 2.1 (1.8–2.5) | 2.3 (1.8–3.1) |
| | Raid Max (chlorpyrifos) | 1.1 (0.3–4.2) | 0.9 (0.6–1.2) |
| | Pic Boric Acid Roach Killer | 0.9 (0.7–0.98) | 0.9 (0.7–1.2) |
| | Combat Roach Killing System | 1.8 (1.6–2.0)* | 2.5 (2.1–3.0)* |
| | Knockdown Pheromone | 3.1 (2.4–3.9)* | 4.2 (2.8–6.3)* |
| | Victor Roach Killing Powder | 0.9 (0.8–1.1) | 0.9 (0.7–1.2) |
| | Raid Ant Bait Plus | 1.3 (.–.) | 1.1 (0.97–1.2) |
| | Roach Prufe | 1.2 (.–.) | 0.9 (.–.) |
| | Concern | 35.8 (1.3–>100)* | 351.7 (1.0–>1000)* |
| Professional | Arthitrol granular | – | – |
| | Arthitrol paste | – | – |
| | Maxforce station | 1.1 (0.9–1.2) | 1.1 (0.9–1.3) |
| | Maxforce gel | 1.6 (1.4–1.7)* | 2.2 (1.9–2.6)* |
| | Siege | 1.2 (1.1–1.5)* | 1.6 (1.2–2.2)* |
| | Strikeforce | 1.6 (0.4–6.9) | 1.2 (0.8–1.8) |
| | Drione | 3.0 (0.2–4.9) | 5.1 (2.1–12.1)* |
| | Invader | 2.0 (0.8–5.5) | 1.2 (0.7–2.4) |
| | Avert PT 300 | 1.2 (1.1–1.3)* | 1.2 (1.1–1.4)* |
| | Avert PT 310 | 1.3 (1.1–1.5)* | 1.1 (0.8–1.4) |
| | Avert Bait | 1.7 (1.4–2.1)* | 0.9 (0.8–1.2) |
| | Alpha 3 | 1.1 (0.9–1.2) | 1.4 (1.2–1.6)* |
| | Drax Roach Kill | 1.6 (1.5–1.8)* | 1.7 (1.3–2.2)* |
| | M.R.F. | 1.6 (1.4–1.7)* | 1.5 (1.2–1.8)* |
| | Niban | 19.5 (2.4–161.6)* | 158.8 (1.7–>1000)* |

Palatability Ratio (PR) describes the effect alternate food has upon the speed of kill in the choice bioassay versus the no-choice bioassay. PR50 and PR95 are the palatability ratios (95% confidence limits) at $LT_{50}$ and the $LT_{95}$ estimates (see Roberston & Preisler 1992, Pesticide Bioassays with Arthropods). PR indicated by "–" were not calculated because there was a single response value and LT estimates were not done in both feeding bioassays. PR with "*" indicate interference to efficacy of the baits caused by the presence of alternate food.

مجلة الإمارات للعلوم الزراعية (١٩٩٧) ٩ : ١-٢٢

# استجابة الصراصير الألمانية للعديد من مستحضرات الطعوم السامة

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ص.ب : ١٧٥٥٥العين – الإمارات العربية المتحدة

ملخص:

تم تحديد استجابة الصراصير الألمانية إلى تسعة طعوم تستخدم من قبل المستهلك و ١٥ طعم تستخدم من قبل المهني . وتختلف هذه الطعوم عن بعضها من حيث المواد الفعالة المحتوية عليها (كلوربايريفوس – سليفلوراميد – هايداميثيلنون – إيباميكتين – بوريك أسيد – بروبوكسور – وسيليكون دايوكسايد) ونوعية مستحضر الطعم (هلامي، معجوني – حبيبي – بودرة – صلب). وقد روعي في تصميم التجارب أن يحدد تأثير الغذاء البديل في تقييم أداء كل طعم. وقد تم تحديد العوامل المؤثرة على تقدير نسبة وفيات الحشرات وهذه العوامل هي: نوع الطعم – طور الحشرة – نوعية الإختبار الغذائي (إختبار إختياري حيث قدمت للحشرات الطعم والغذاء البديل الغير سام بآن واحد، واختبار إجباري حيث قدمت للحشرة الطعم فقط).

أظهرت النتائج أن نوع الطعم له الدور الأساسي في شرح المتغيرات الاختيارية المتعلقة بنسبة معدل وفيات الحشرات بعد ٣و٧ و ١٤ يوم من بداية تقديم الطعوم. وكان دور نوع الطعم السام أكثر أهمية من دور طور الحشرة أو الاختبار الغذائي.وقد كانت فعالية الطعوم السامة غير متساوية في قتل الحشرات المدروسة. حيث ظهرت الاختلافات بين قيم الوقت اللازم لقتل ٥٠% و ٩٥% من تعداد الحشرات (LT95, LT50 على التوالي) لكل أنواع الطعوم وفي كل من اختباري الغذاء.

استنادا إلى قيم الوقت النصفي القاتل (LT50) لأنواع الطعوم المستعملة من قبل المستهلك فقد تبين أن Raid Max (Chlorpyriphos) كان أكثر الطعوم تقبلا من قبل الحشرات وأسرع الطعوم في قتلهم (LT50 = 0.3 يوم) في كل من اختباري الغذاء. بينما أعتبر الطعم Concern أقل الطعوم تقبلا من قبل الحشرات وأبطئها في قتلهم. وقد تم

ترتيب سمية الطعوم المستعملة من قبل المستهلك في اختبار الغذاء الإختياري. وقد سببت أغلب الطعوم السامة ١٠٠% نسبة قتل للحشرات عند نهاية التجارب اعتبرت أفضل من الطعم Concern في اختبار الغذاء الإجباري وأفضل من الطعوم Concern, Knockolown, Combat في اختبار الغذاء الإختياري.

استنادا إلى LT50s لأنواع الطعوم المستعملة من قبل المهنيين، تعتبر المستحضرات Strikeforce, Drione, Arthitrol من أفضل الطعوم تقبلاً من قبل الحشرات وأسرعها في قتلهم في كل من اختباري الغذاء (LT50 = أقل من يوم). واعتبرت الطعوم المحتوية على بوريك اسيد (Niban , MRF , Drax, Alpha3) من أقل الطعوم تقبلاً للحشرات وأبطئها في قتلهم. وقد تم ترتيب سمية الطعوم في إختباري الغذاء الإختياري. وقد سببت أغلب الطعوم ١٠٠% نسبة قتل للحشرات عند نهاية فترة التجارب اعتبرت أفضل من الطعوم Niban , MRF, Drax في كل من إختباري الغذاء.

وقد أظهرت النتائج أن نسب استساغة الطعوم (Palatability Ratios) قدرت بأكثر من ١ من قبل الحشرات وكانت متغيرة. وهذه القيمة تؤكد وجود مادة مانعة أو عائقة للتغذية ومع ذلك فإن حجم هذا العائق الغذائي صغير، وقد عزيت القيم الناتجة إلى حد بعيد إلى التغذية العشوائية لهذه الحشرات.

**كلمات مفتاحية:** طعم سام، Dictyoptera, Blattellidae, *Blattella germanica*