Residual Activity and Population Effects of Noviflumuron for German Cockroach (Dictyoptera: Blattellidae) Control

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ABSTRACT A benzoylphenyl urea insect growth regulator with the common name noviflumuron was evaluated for efficacy and residual activity on the German cockroach, *Blattella germanica* (L.). In laboratory studies evaluating residual activity, 0.05% noviflumuron suspension concentrate produced 100% nymphal mortality 120 d after application to steel and masonite substrates. Residual activity of noviflumuron was more variable on painted plywood substrates compared with stainless steel and masonite. In bioassay arenas, population reductions caused by noviflumuron were significantly greater than Archer and the untreated populations. After 16 wk, populations exposed to 0.05, 0.1, and 0.2% noviflumuron were reduced by 51.9 ± 19.8, 62.2 ± 6.5, and 62.6 ± 18.4%, respectively. Control cockroach populations and populations exposed to 1.3% pyriproxyfen at labeled rate (Archer, 0.61 g/m^2) increased by 1,286.3 ± 125.1 and 937.2 ± 137.1%, respectively, at the end of 16 wk. A field study in multifamily housing complexes showed noviflumuron (0.2 and 0.5%) to provide 73.3 ± 8.0 and 90.6 ± 3.6% trap catch reduction at 4 wk posttreatment, respectively. There were no significant differences in the performance of noviflumuron, Maxforce FC Roach Bait Stations (0.05% [AI] fipronil), and Avert dust bait (0.05% [AI] abamectin B1). Noviflumuron shows excellent potential for use in cockroach management programs.

KEY WORDS noviflumuron, chitin synthesis inhibitor, German cockroach, residual control, multifamily housing

THE USE OF CONVENTIONAL insecticides remains an integral part of pest management programs for the German cockroach, *Blattella germanica* (L.), with many chemical classes currently available in a variety of formulations (Koehler et al. 1995, Wickham 1995, Benson and Zungoli 1997). Because of human safety and insecticide resistance issues, development of new or lesser used insecticide classes for cockroach management is needed. Insect growth regulators (IGRs) are a desirable alternative for cockroach management because they are selective to insect pest targets and therefore ideal for use in programs for minimizing insecticide resistance (Bennett and Reid 1995). Currently, only IGRs that are juvenile hormone analogues (JHAs) have been registered for control of *B. germanica*, and they have considerable potential for population management (Bennett et al. 1986, Ogg and Gold 1988, Reid et al.1990, Kaakeh et al. 1996). However, JHAs applied alone produce relatively slow population control for *B. germanica* and are typically recommended for use in combination with a faster acting insecticide (Bennett and Reid 1995).

Another group of IGRs under consideration for cockroach population management are benzoylphenyl ureas (BPUs) that inhibit chitin synthesis in *B. germanica*, thus preventing successful nymphal molting, and sometimes are ovicidal (Weaver et al. 1984; Koehler and Patterson 1989; DeMark and Bennett 1989, 1990; DeMark et al. 1989). Because BPUs affect multiple life stages of the *B. germanica* more rapidly than juvenoids, they have greater potential as an IGR alternative for cockroach population management programs (Bennett and Reid 1995). In field trials, the BPU flufenoxuron significantly decreased *B. germanica* populations 4–6 wk after application and produced acceptable levels of control within 8 wk (Reid et al. 1992). Although research results have been promising, no BPUs are currently registered for cockroach control in the United States.

Noviflumuron, *N*-[[[3,5-dichloro-2-fluoro-4-(1,1,2,3,3,3-hexafluoropropoxy) phenyl]amino]carbonyl]-2,6-difluorobenzamide, is the common name for a new BPU compound produced by Dow AgroSciences (Indianapolis, IN) that has shown excellent control for

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several urban insect pests (DeMark 2002, Smith et al. 2002, Suiter 2002, Karr et al. 2004). Noviflumuron is the new bait toxicant for subterranean termites in the Sentricon Termite Colony Elimination System (Dow AgroSciences). Noviflumuron demonstrated significantly greater potency and faster speed of action than the BPU hexaflumuron, the previous bait toxicant for the Sentricon System (Smith et al. 2002, Karr et al. 2004). The faster activity of noviflumuron compared with hexaflumuron in the eastern subterranean termite, *Reticulitermes flavipes* (Kollar), can be at least partially explained by the combination of slower clearance (the ability of termites to remove noviflumuron from their bodies) and greater intrinsic activity (Karr et al. 2004).

Noviflumuron also has produced promising results for control of cockroach field populations, with performance equivalent to other commonly used insecticides (Ameen et al. 2002). Early stage laboratory tests on *B. germanica* revealed that noviflumuron is effective only as an oral toxicant, with little potential to penetrate the insect cuticle (L.L.K., unpublished data). This is typical for most BPU insecticides, which require ingestion by insects for toxicity (Mulder and Gifswijt 1973). However, in surface-contact bioassays, residual formulations of BPUs have high toxicity to *B. germanica* (Reid and Bennett 1989, Kaakeh and Bennett 1996), presumably by ingestion from grooming spray deposits from the antennae and tarsi (Bennett and Reid 1995). In this article, we report on the activity of a residual formulation of noviflumuron on *B. germanica*, and its comparative effects with other insecticide formulations on cockroach populations in laboratory and under field conditions.

Materials and Methods

Residual Activity Study. The objective of this assay was to evaluate the residual activity of noviflumuron suspension concentrate (SC) after application to three different types of substrates: stainless steel, polished masonite, and latex-painted plywood. Noviflumuron SC (12% [AI]) was diluted in water to a concentration of 0.05% and applied to 30.5 by 30.5-cm panels at a spray volume of 40.7 ml/m^2 (1 gal/1000 ft^2) with a Mandel track sprayer (8003E nozzle). The final deposit on each substrate was 5.38 mg/m^2. Water was used as the control treatment. Both the noviflumuron and water treatments were replicated four times for each type of substrate.

After drying, panels were stored horizontally under ambient laboratory conditions, which typically ranged from 21 to 24°C and 40–60% RH. At 7, 30, and 120 d posttreatment, 10 second or third instars of *B. germanica* (laboratory-susceptible strain) were confined on treated substrates for 20 min under petri dish lids (100 mm). A different portion of each panel was used to expose the nymphs at each of the three postapplication intervals. After exposure, nymphs were placed in plastic petri dishes (100 by 25 mm) containing a water source (2-dram vial with dental wick) and one nugget of dog chow. The insects were held in petri dishes at 21–24°C, 40–60% RH, and a photoperiod of 13:11 (L:D) h. Food and water were replenished to each dish as needed. Cockroaches were monitored weekly for morbidity and mortality with final mortality recorded at 28 d postpanel exposure.

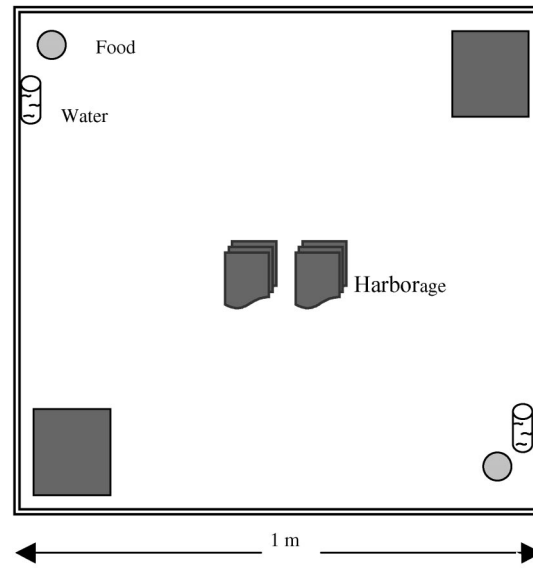

Fig. 1. Test arena for laboratory population study.

Laboratory Population Study. Noviflumuron SC and Archer (1.3% [AI] pyriproxyfen, Zeneca Professional Product, Wilmington, DE) were evaluated for control of populations of a laboratory-reared, insecticide-susceptible JWAX strain of *B. germanica* (Koehler and Patterson 1986). Archer is a juvenoid IGR registered for control of cockroaches. Thus, this study allowed for a direct comparison between a BPU IGR and juvenoid IGR. The JWAX cockroach strain has been maintained in culture at the Center for Urban and Industrial Pest Management, Purdue University, West Lafayette, IN, since 1984 on a standard laboratory diet of Wayne Rodent Blox (Continental Grain, Chicago, IL) at 26–27°C, 60–70% RH, and a photoperiod of 12:12 (L:D) h.

Studies were conducted in 1-m^2 Plexiglas arenas in an 11 by 14.5-m room with a controlled environment (27°C, 50% RH, and a photoperiod of 12:12 [L:D] h). Each arena was provided with a harborage that consisted of five masonite panels separated by 5-mm spacers. One additional harborage was added to each arena at the middle of the experiment to accommodate increasing number of cockroaches. Abundant food and water was provided. Water was provided in cotton-plugged 25-ml vials, and Rodent Blox was positioned in opposite corners of the arenas. Five hundred insects, consisting of 270 second and third instars, 105 fourth and fifth instars, 65 males and 42 nongravid females, and 18 gravid females were released into the arenas and allowed 3 d to acclimate before treatments were applied (Fig. 1).

Four treatments, 0.05, 0.1, and 0.2% noviflumuron SC, and Archer were applied onto masonite panels

Table 1. Percentage of mortality (28 d postexposure) of *B. germanica* nymphs (second and third instars) exposed to aged pesticide residues (0.05% noviflumuron SC) for 20 min on different substrates ($n = 3$)

Treatment	Substrate type	Mean % mortality at 28 d postexposure		
		Age of treated substrate (d)		
		7	30	120
Noviflumuron	Stainless steel	100.00 ± 0.00a	100.00 ± 0.00a	100.00 ± 0.00a
Noviflumuron	Masonite	100.00 ± 0.00a	100.00 ± 0.00a	100.00 ± 0.00a
Noviflumuron	Painted plywood	97.50 ± 2.50a	62.50 ± 6.29b	85.00 ± 9.57a
Water	Stainless steel	12.50 ± 4.79b	10.00 ± 4.08c	12.50 ± 2.50b
Water	Masonite	2.50 ± 2.50b	0.00 ± 0.00d	7.50 ± 4.79b
Water	Painted plywood	12.50 ± 4.79b	5.00 ± 2.89cd	2.50 ± 2.50b

Within each column, means followed by different letters were significantly different ($P \leq 0.05$, LSD).

(15.24 by 15.24 cm) by using a spray tower (Spraying System Tee-Jet SS8001E, Dayton Electric Manufacturing Company, Chicago, IL) with a flat fan stainless steel nozzle. The spray rate for noviflumuron SC was 40.7 mg/m^2 (1 gal/1000 ft^2) of formulated material. Archer was sprayed at the labeled rate, i.e., 0.61 g/m^2 (2 oz/1000 ft^2). Two sprayed panels were placed at opposite corners of the arenas. Untreated panels were placed in arenas in the control. Treatments were replicated three times. Tests lasted for 16 wk after treatments were introduced. Cockroaches were exposed to the panels for 16 wk. The number of living cockroaches was counted weekly and classified by stage. Dead cockroaches were removed from the arenas weekly.

Field Study. The residual efficacy of noviflumuron SC at 0.2 and 0.5% on field *B. germanica* populations was evaluated at multifamily housing complexes located in Fort Wayne and Muncie, IN, during May–November 1998. The standard treatments were Avert PT 310 dust bait (0.05% [AI] abamectin B1; Whitmire Micro-Gen Research Laboratories, Inc., St. Louis, MO) and Maxforce FC Roach Bait Stations (0.05% [AI] fipronil, Maxforce Insect Control Systems, Oakland, CA). Before the beginning of the study, the housing authorities were advised to terminate all insecticide applications at least 4–6 wk in advance. Sticky traps (10 by 19 cm, Agrisense Lo-Line, Palo Alto, CA) were used to measure the impact of treatments on populations. One monitoring trap was placed in each of the following areas: 1) the cabinetry under the kitchen sink, 2) the cabinetry above the kitchen sink, 3) beside the stove, 4) beside the refrigerator, 5) in the utility room (area around water heater and furnace), and 6) behind the toilet on the floor. The traps were placed such that one of the enclosed sides was touching a wall or a vertical component of the cabinetry. Traps were placed 1 d and retrieved ≈24 h later. The number of cockroaches was counted and recorded by trap as number of males, females, gravid females, large nymphs (instars 4–6), and small nymphs (instars 1–3). A minimum of 12 cockroaches caught in six traps (i.e., an average of two cockroaches per trap) was required for any apartment to be selected as a test apartment. Treatments were assigned to apartments in such a way as to ensure reasonably equivalent pretreatment cockroach trap counts. At least eight apartments were identified for each treatment. Apartments in the same building received same treatment.

In apartments treated with noviflumuron, the insecticide was applied to cracks and crevices using a B & G sprayer (B & G Equipment Co., Plumsteadville, PA) at a pressure of 20 psi. Approximately 200 ml of formulated material was sprayed in each test apartment. In apartments treated with bait stations, 12 Maxforce FC bait stations were deployed. In apartments treated with Avert dust, the dust was applied at the rate of 15 g per apartment. Posttreatment populations were monitored at 2, 4, 8, 12, 18, and 24 wk. Treatments were reapplied after the 12 wk posttreatment population sampling was concluded.

Data Analyses. For the laboratory residual activity study, analysis of variance with Fisher's protected least significant difference (LSD) comparisons was used (Minitab Inc. 1998) to determine significant differences ($P = 0.05$) in transformed (arcsine $\sqrt{P}$) percentage of mortality between treatments after 28 d postexposure to treated substrates.

For the laboratory and field population studies, the numbers of live cockroaches (n) were transformed by log (n + 1) –log (n_0 + 1), where n_0 was the initial number of cockroaches before treatments were applied. The transformed data were analyzed using a mixed effects model repeated measures approach (PROC MIXED, SAS Institute 2001). For population count data, the fitted slopes of the weeks were compared to determine the overall differences among treatments. Means at each period were assessed to determine differences among treatments for each period. The nymphal ratios, where the total number of cockroaches was >9 in an experiment unit, also were analyzed using a mixed effects model repeated measures approach.

Results

Residual Activity Study. For each aging period, nymphal *B. germanica* exposed to noviflumuron typically began to express symptoms of moribundity and mortality on each type of substrate shortly after 7 d postexposure. Compared with the water controls, 0.05% noviflumuron caused significant mortality (28 d postexposure) on substrates aged for 7 d ($F = 74.91$; df = 5, 15; $P < 0.001$), 30 d ($F = 116.56$; df = 5, 15; $P < 0.001$), and 120 d ($F = 52.5$; df = 5, 15; $P < 0.001$)

Table 2. Comparative efficacy of noviflumuron for control of laboratory *B. germanica* populations

Wk	Survival (mean ± SE)				
	0.05% Noviflumuron	0.1% Noviflumuron	0.2% Noviflumuron	Archer	Untreated control
0	502.3 ± 38.7a	504.3 ± 18.1a	466.0 ± 18.7a	505.0 ± 15.5a	497.3 ± 31.8a
1	316.3 ± 46.7b	321.0 ± 34.9b	334.3 ± 34.9b	500.7 ± 36.0a	522.7 ± 41.6a
2	108b	180b	166ab	456a	452a
3	302.0 ± 123.1c	607.7 ± 80.1ab[a]	423.3 ± 181.1bc	456.0 ± 151.2a	1,137.7 ± 346.2a
4	303.7 ± 50.0b	408.3 ± 135.6b	397.7 ± 120.1b	880.0 ± 77.7a	1,150.7 ± 38.4a
5	141.3 ± 35.7b	229.0 ± 70.6bc	315.7 ± 88.9c	927.7 ± 101.5a	1,612.7 ± 182.5a
6	131.0 ± 28.0b	149.0 ± 7.5b	149.7 ± 5.7b	1,225.0 ± 520.9a	2,381.7 ± 475.3a
7	140.7 ± 35.1b	136.3 ± 7.1b	131.0 ± 4.4b	2090.7a	2,234.0a
8	117.7 ± 38.4c	125.7 ± 2.9c	116.7 ± 4.3c	1,802.0 ± 314.5b	4,836.0 ± 1,083.0a
9	149.7 ± 42.3b	122.0 ± 3.8b	115.3 ± 6.4b	1,915.3 ± 158.3a	5,529.3 ± 1,260.3a
10	162.0 ± 51.0b	108.0 ± 1.2b	101.3 ± 6.9b	2,848.3 ± 174.1a	5,283.3 ± 863.7a
11	205.7 ± 96.8b	175.0 ± 70.0b	178.0 ± 85.6b	2,977.7 ± 218.4a	5,662.7 ± 690.3a
12	313.0 ± 135.7b	203.3 ± 11.7b	116.3 ± 12.5b	3,199.0 ± 515.8a	5,391.0a
13	318.0 ± 107.8b	127.3 ± 20.2c	78.3 ± 8.4c	3,103.7 ± 321.8a	6,146.3 ± 273.4a
14	254.4 ± 107.8b	134.3 ± 36.8b	70.3 ± 3.7c	3,495.7 ± 188.7a	7,067.0 ± 445.7a
15	267.3 ± 121.9b	184.7 ± 62.2b	83.3 ± 14.3c	3,878.7 ± 366.2a	7,495.0 ± 206.6a
16	242.3 ± 101.0b	188.7 ± 26.3b	172.0 ± 84.3b	4,685.3 ± 695.6a	6,827.7 ± 349.7a

Mean of three replicates. Those without SE were from one replicate. Within each row, means followed by different letters were significantly different ($P \leq 0.05$).

[a] Large numbers of nymphs emerged from one replicate.

(Table 1). On stainless steel and masonite, 0.05% noviflumuron provided 100% mortality (28 d postexposure) at each aging period through 120 d. On latex-painted plywood, noviflumuron residual activity was significantly ($P \leq 0.05$, LSD) lower than the other two substrates after 30 d of aging. There was no significant ($P > 0.05$, LSD) difference in residual activity between substrates after 30 d.

Laboratory Population Study. There were no significant differences among the three noviflumuron treatments. They all caused significantly higher population reduction than the Archer and the control ($P \leq 0.05$). The cockroach population in the untreated control increased to 6,828 ± 350 at week 16, which was 1,286.3 ± 125.1% of the initial population. Archer failed to provide effective control of the cockroach populations, which increased 937.2 ± 137.1% by week 16. Weekly comparisons showed Archer was associated with lower populations than the control only at week 8 ($P = 0.02$). In contrast, all concentrations of noviflumuron SC caused significantly lower populations than Archer and the control except for 0.1% noviflumuron at week 3 ($P \leq 0.05$) (Table 2). At week 16, the average population reduction of the 0.05, 0.1, 0.2% treatments were 51.9 ± 19.8, 62.2 ± 6.5, and 62.6 ± 18.4%, respectively. Weekly comparisons also showed that 0.05% noviflumuron was less effective than 0.1% and 0.2% noviflumuron at a weeks 3, 5, and 13–15. As expected, the decrease of the cockroach populations was mainly due to the nymphal mortality. The nymphal ratios (nymph/total) of the three noviflumuron treatments were significantly lower than

Table 3. Effect of noviflumuron on laboratory *B. germanica* population structure

Wk	Nymph/total ratio (mean ± SE)				
	0.05% Noviflumuron	0.1% Noviflumuron	0.2% Noviflumuron	Archer	Untreated control
1	0.64 ± 0.05a	0.63 ± 0.04a	0.63 ± 0.04a	0.67 ± 0.04a	0.68 ± 0.02a
2	0.5a	0.23a	0.07b	0.53a	0.60a
3	0.51 ± 0.20a	0.81 ± 0.02b	0.55 ± 0.19a	0.68 ± 0.05a	0.70 ± 0.07a
4	0.66 ± 0.12a	0.59 ± 0.21a	0.62 ± 0.14a	0.75 ± 0.02a	0.76 ± 0.01a
5	0.11 ± 0.06b	0.29 ± 0.22bc	0.48 ± 0.23c	0.79 ± 0.02a	0.82 ± 0.01a
6	0.04 ± 0.01b	0.02 ± 0.01b	0.04 ± 0.04b	0.86 ± 0.04a	0.88 ± 0.01a
7	0.13 ± 0.09b	0.03 ± 0.02b	0.01 ± 0.01b	0.85a	0.9a
8	0.26 ± 0.13b	0.05 ± 0.02b	0.02 ± 0.01b	0.88 ± 0.02a	0.93 ± 0.01a
9	0.37 ± 0.10b	0.03 ± 0.01c	0.02 ± 0.01c	0.88 ± 0.02a	0.90 ± 0.03a
10	0.37 ± 0.19b	0.04 ± 0.01c	0.02 ± 0.01c	0.88 ± 0.01a	0.89 ± 0.01a
11	0.59 ± 0.14bc	0.41 ± 0.23c	0.46 ± 0.24c	0.87 ± 0.01a	0.82 ± 0.02ab
12	0.67 ± 0.20a	0.77 ± 0.03a	0.61 ± 0.06a	0.82 ± 0.03a	0.79a
13	0.84 ± 0.07a	0.64 ± 0.06ab	0.38 ± 0.01b	0.86 ± 0.02a	0.77 ± 0.02a
14	0.70 ± 0.22a	0.62 ± 0.14ab	0.29 ± 0.13b	0.84 ± 0.01a	0.72 ± 0.04a
15	0.74 ± 0.18a	0.76 ± 0.09a	0.47 ± 0.13b	0.86 ± 0.01a	0.84 ± 0.05a
16	0.71 ± 019a	0.81 ± 0.05a	0.69 ± 0.11a	0.86 ± 0.01a	0.86 ± 0.07a

Mean of three replicates. Those without SE were from one replicate. Within each row, means followed by different letters were significantly different ($P \leq 0.05$).

Table 4. Effect of selected insecticides on field *B. germanica* populations

Treatment	Trap catch reduction (mean ± SE)					
	Week 2	Week 4	Week 8	Week 12	Week 18	Week 24
Maxforce FC	57.9 ± 17.2 (9)a	69.4 ± 10.8 (9)ab	84.1 ± 5.9 (9)a	83.3 ± 6.8 (9)a	83.6 ± 7.0 (8)a	89.5 ± 5.7 (8)ab
Avert	54.2 ± 14.8 (8)a	57.0 ± 12.2 (8)a	65.1 ± 24.0 (8)a	90.1 ± 4.4 (8)a	72.4 ± 19.5 (7)a	71.4 ± 13.7 (6)a
0.5% Noviflumuron	63.2 ± 7.9 (8)a	73.3 ± 8.0 (8)ab	85.9 ± 6.0 (8)a	95.2 ± 1.8 (8)a	98.4 ± 0.8 (6)a	94.5 ± 4.0 (4)ab
0.2% Noviflumuron	72.2 ± 8.0 (9)a	90.6 ± 3.6 (9)b	58.6 ± 35.3 (9)a	81.0 ± 14.0 (9)a	98.1 ± 0.9 (8)a	99.9 ± 0.1 (6)b

Values in parentheses are numbers of apartments in each treatment group. Means within each column followed by different letters were significantly different ($P \leq 0.05$).

those of the Archer and the untreated control during week 5–10 ($P \leq 0.05$) (Table 3). The 0.1% and 0.2% noviflumuron treatments also caused significantly lower nymphal ratios than the 0.05% noviflumuron treatment at weeks 9 and 10. The number of nymphs increased after week 10 as a result of the emergence of small nymphs.

Field Study. The average number of cockroaches per trap prior to treatment was 22.1 ± 7.9, 11.8 ± 3.9, 22.1 ± 8.2, and 16.4 ± 5.5 for the 0.2% noviflumuron, 0.5% noviflumuron, Avert dust bait, and Maxforce FC bait station treatments, respectively. At week 4, 0.2 and 0.5% noviflumuron treatments provided 73.3 ± 8.0 and 90.6 ± 3.6% trap catch reduction, respectively. At week 12, all treatments produced ≥81% catch reductions (Table 4). Average trap catch reduction for 0.2% noviflumuron SC, 0.5% noviflumuron SC, Avert dust, and Maxforce FC bait station at week 24 were 99.9 ± 0.1, 94.5 ± 4.0, 71.4 ± 13.7, and 89.5 ± 5.7%, respectively. Overall, comparisons showed there were no significant ($P > 0.05$) differences among noviflumuron SC, Maxforce FC bait station, and Avert dust bait treatments in trap catches. Weekly comparisons indicated that 0.2% noviflumuron treatment had lower trap catch counts than Avert dust treatment at weeks 4 and 24 ($P \leq 0.05$) (Table 4).

The 0.5% noviflumuron treatment caused significantly lower nymphal ratios (nymph/total) than Maxforce FC treatment at weeks 2 and 4 (Fig. 2). It also caused a significantly lower nymphal ratio than the Avert treatment at week 4. The 0.2% noviflumuron treatment caused significantly lower nymphal ratios than the Avert and Maxforce FC treatments at week 2.

Discussion

The results of the residual activity study indicated that noviflumuron was very effective at killing *B. germanica* via exposure to residual surface deposits. Noviflumuron also has the potential to provide long-term residual control of cockroaches on a variety of substrates. Residual efficacy of noviflumuron was more variable on painted plywood substrates compared with stainless steel and masonite. Kaakeh and Bennett (1996) found that residual spray deposits of the lufenuron provided better cockroach control when applied on clean masonite surfaces than on painted plywood. Historical data from examinations of other residual insecticides have shown the reduced efficacy with latex paint; however, there is a lack of sufficient information explaining these results (Rust 1995).

In our laboratory arena study, population decreases caused by noviflumuron were highly significant (compared with untreated populations) beginning at 4 wk postexposure. Our results corroborate with those of earlier tests with BPU-IGRs on laboratory populations of *B. germanica* (Bennett and Reid 1995). In contrast, cockroach populations exposed to the juvenoid IGR (Archer) increased significantly after 4 wk of contact exposure. This lack of efficacy indicated the label

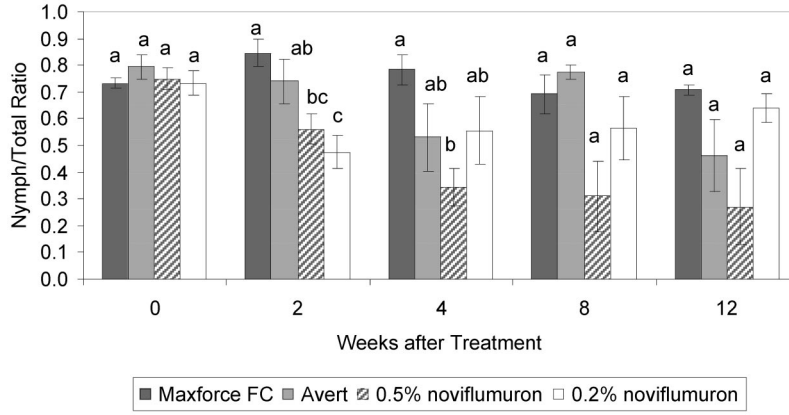

Fig. 2. Effect of selected insecticides on field *B. germanica* population structure. Bars with different letters are significantly different ($P \leq 0.05$, LSD).

application rate was too low under these test conditions. Previous field studies on *B. germanica* indicate that a posttreatment period from 4 to 6 mo must elapse before significant population reductions will occur for juvenoid IGR treatments that are applied alone (Bennett et al. 1986, Ogg and Gold 1988, Reid et al.1990). In contrast, the BPU-IGR in this laboratory study (noviflumuron) demonstrated the potential to provide timely, effective population control.

Both laboratory and field experiments showed that noviflumuron caused significantly lower nymphal ratios compared with untreated control or fipronil. The lower nymphal ratios demonstrated the effectiveness of noviflumuron as a chitin synthesis inhibitor, which caused the death of nymphs and sterility of the females. The rebound of the nymphal ratios in the laboratory experiment at 11 wk was probably due to lack of sufficient amount active ingredient to suppress the female fecundity. We expect that additional applications of the noviflumuron SC might prevent the emergence of nymphs and produce higher reduction at 16 wk in the laboratory study.

Previous field trials with noviflumuron have shown great potential for control of *B. germanica* by using formulations (bait and dust) considered optimal for delivery of oral toxicants (Ameen at el. 2002). Results of the field trial reported here indicate that a residual formulation of noviflumuron applied to surfaces also can suppress cockroach populations to a level that is comparable in performance to commonly used insecticide formulations. Field results showed noviflumuron to provide a high level of population reduction beginning after 8 wk posttreatment, with maximal effects seen at 12–24 wk. These findings were similar to field results achieved on *B. germanica* with the BPU flufenoxuron in a wettable powder spray formulation (Reid et al. 1992). Noviflumuron seems to be an excellent alternative to conventional insecticides and has the potential of being an important element in cockroach management programs.

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