Red Imported Fire Ant (Hymenoptera: Formicidae) Control with a Corn Grit Bait of Fenoxycarb without Soybean Oil

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ABSTRACT The standard fenoxycarb fire ant bait formulation (Logic), composed of pregel defatted corn grits and soybean oil toxicant, was modified by eliminating the soybean oil. This formulation without soybean oil contained >2 times more fenoxycarb and was as effective as the standard bait formulation against laboratory colonies of red imported fire ant, *Solenopsis invicta* Buren. In field tests, the modified and standard baits were equally effective in controlling fire ants after 6, 12, and 18 wk. Individual worker ants obtained from plots treated with fenoxycarb baits without soybean oil had >47 times less fenoxycarb than did workers from the plots treated with the standard fenoxycarb baits containing soybean oil.

KEY WORDS Insecta, *Solenopsis invicta*, baits, fenoxycarb

THE RED IMPORTED FIRE ANT, *Solenopsis invicta* Buren, introduced into the United States in the 1930s, has become a serious pest of man in the southeastern and parts of the southwestern United States (Lofgren et al. 1975, Adams 1986, Lofgren 1986). This ant continues to spread and may establish populations in New Mexico, Arizona, and California. The increasing incidence of the polygyne (multiple queen) form poses an additional problem, not only to humans and agricultural crops but also to wildlife, especially surface-active animals (Porter & Savignano 1990).

Baits have been used to control the fire ant since mirex was discovered in the early 1960s (Lofgren et al. 1963, 1964b). However, serious concerns regarding residues in the environment led the U.S. Environmental Protection Agency to ban use of mirex in 1978 (Johnson 1976). New baits developed in the early to mid-1980s were based on a formulation similar to that of mirex bait; i.e., a chemical dissolved in once-refined soybean oil and applied to a corn grit carrier (Williams et al. 1980, Lofgren & Williams 1982, Banks et al. 1983). Because they degrade rapidly and leave no known residues, the new toxicants are less hazardous to the environment. However, other problems are the (1) attractiveness of the formulations to nontarget insects that also feed on the bait and are affected by the toxicants (Williams 1986), (2) flowability and dispersal of the baits, (3) poor shelf life of the formulations because of rancidity of the soybean oil, and (4) high cost.

Development of formulations that eliminate or reduce bait effects on nontarget ants should be a high priority, considering the role that the native ant community plays (Whitcomb et al. 1973, Nickerson et al. 1975, Buren et al. 1978, Lammers 1987). Although this study was not conducted to address this issue, a reduction or the removal of the soybean oil in toxic baits may lessen the effect these baits have on some of the nontarget ant species. Also, baits without soybean oil should solve some of the other problems mentioned above such as flowability, rancidity, and cost. Removal of the soybean oil, of course, must not be at the expense of reducing bait effectiveness. Therefore, the purpose of this study was to evaluate efficacy of a bait formulation containing fenoxycarb (Maag Agrochemicals, Inc., Vero Beach, Fla.) but no soybean oil against the red imported fire ant.

Materials and Methods

Laboratory procedures for evaluating bait toxicants have been described fully (Williams et al. 1980, Williams 1983, Banks et al. 1988). Because fenoxycarb causes little mortality in worker ants (Banks et al. 1988), this study was designed to determine overall effects of the baits on whole colonies. The formulations were tested against monogyne queenright laboratory colonies (12–18 mo old) containing 35,000–45,000 workers and 10–20 ml of brood (eggs, larvae, and pupae). The colonies were reared as described by Banks et al. (1981), except the diet consisted of honey/water (1:1), hard-boiled chicken eggs, and house fly pupae. Colonies were held without food for 5 d before the test.

Baits for both laboratory and field tests were prepared in the same manner. Baits without soybean oil (NOSBO) were formulated by immersing

Table 1. Mean percentage mortality and bait removed and time of queen death in laboratory colonies of red imported fire ants offered pregel defatted corn grit (PDCG)–acetone immersion (without soybean oil) and PDCG–soybean oil-formulated baits containing fenoxycarb

Treatment	n	% Bait removed by workers, $\bar{x} \pm$ SEM	Week when queens in all colonies (replications) were dead	% Worker mortality 21 wk after treatment, $\bar{x} \pm$ SEM
Fenoxycarb–NOSBO	5	69.6 ± 14.5	15	71.9 ± 9.6
Fenoxycarb–SBO	2	50.0 ± 0.0	7	62.5 ± 12.5
Control–NOSBO	5	90.0 ± 10.0	0[a]	7.4 ± 3.7
Control–SBO	2	100.0 ± 0.0	0[a]	4.5 ± 0.5
Contrasts:[b]				
SBO versus NOSBO	—	0.12	—	0.32
Fenoxycarbs versus controls	—	6.34*	—	31.41**
Fenoxycarb–SBO versus fenoxycarb–NOSBO	—	1.00	—	0.56

[a] No queens dead after 21 wk.
[b] F values for contrasts determined to be significant (*, $P \leq 0.05$), highly significant (**, $P \leq 0.01$); otherwise, data not significant ($P \leq 0.05$; orthogonal comparisons using GLM [SAS Institute 1988]).

the carrier, pregel defatted corn grits (Lauhoff Grain, Danville, Ill.), for 30 min in an acetone solution containing 2.5% by weight of technical fenoxycarb. Grits were subsequently removed and air-dried for 24 h in a shallow pan in a fume hood. The bait was ready for use when dry. The standard soybean oil bait (SBO) was formulated by dissolving 2.5% by weight of fenoxycarb in once-refined soybean oil. The solution was then impregnated on pregel defatted corn grits at 30% by weight of total formulation.

Five grams of formulated bait was offered in a disposable weigh boat (100 ml capacity) to each laboratory colony. Ants were allowed ad libitum feeding for 96 h; any remaining bait was removed and replaced with the standard diet. Worker mortality and queen status (dead or alive) were observed weekly for 21 wk. The fenoxycarb-NOSBO bait was tested against five colonies, and the formulation with SBO was tested against two colonies. Control colonies were offered formulations without toxicant (NOSBO, five colonies; SBO, two colonies).

The field tests were conducted in Brooks County, Ga. The baits were applied to 1.2-ha plots in nongrazed permanent pasture with a tractor-mounted auger applicator (Williams et al. 1983) at a rate of 1.12 kg/ha. Each treatment was applied to three plots, and three plots were left untreated as controls.

Treatment efficacy was determined on three 0.2-ha circles within each treatment and control plot. The plots were arranged in a completely randomized design. The evaluation method described by Lofgren & Williams (1982) was used to rate each colony before treatment and at 6, 12, and 18 wk after treatment. This method assigns a rating of 1 to 25 based on colony size (number of workers ranging from <100 workers to >50,000) and the presence (normal) or absence (abnormal) of worker brood. The total of the ratings for all colonies on a plot yields the "population index" (PI) for that plot. The difference between the before- and after-treatment population indices was used to calculate the percentage control for each treatment.

Quantitative Analysis for Fenoxycarb. A 2-g sample of fenoxycarb-NOSBO and SBO baits was collected immediately before application. Three days after the treatments were applied, samples of about 1,000 worker ants were collected from individual mounds in the treatment plots by pushing a 20-ml scintillation vial, its inner wall coated with talc, into the mound so that its top rim was slightly below the soil. After a sample of worker ants had fallen into the vial, it was capped and taken to the laboratory. The samples (baits and individual worker ants) were weighed and extracted three times in acetonitrile. The combined extracts of each sample type were filtered via syringe through a 13-mm, 5-μ Zefluor filter in a Swinny stainless steel apparatus. The filter was washed with an additional volume of fresh acetonitrile. The sample was evaporated to dryness and reconstituted with a suitable volume of acetonitrile (500 μl for samples containing 1–10 ng analyte/mg sample). This was again filtered. Ten μl of the filtrate was injected onto a Varian MCH-10 reverse-phase HPLC column and eluted with a solution of $MeOH/H_2O/AcOH$ (65:35:0.3). The eluant was directed through a Perkin Elmer LC-75 variable-wavelength UV/VIS detector set at 228 nm. The column flow rate was 1.5 ml/min. Data were analyzed with a Varian Vista 401 data processor. Standard calibration curves were prepared from an analytical sample of fenoxycarb (Maag). Samples were quantified by comparison with the standard curve. Samples were replicated (n = 2), and the means and standard deviations were recorded.

The arcsine transformation was performed on all percentage data so the resulting data would have a nearly normal distribution. General linear models (GLM) (SAS Institute 1988) and orthogonal comparisons were performed. Specific contrasts for the

Table 2. Effects of granular baits containing fenoxycarb with and without soybean oil on field populations of monogyne colonies of red imported fire ants

Treatment	Rate, g (AI)/ha	n	Pretreatment population index, $\bar{x} \pm$ SEM	% Reduction in population index at weeks indicated, $\bar{x} \pm$ SEM[a]		
				6	12	18
Fenoxycarb–SBO	9.4	3	503.7 ± 27.4	76.7 ± 3.4	94.0 ± 1.5	98.7 ± 0.9
Fenoxycarb–NOSBO	23.1	3	566.3 ± 57.0	76.3 ± 4.1	89.6 ± 3.9	97.0 ± 1.5
Control (untreated)	—	3	463.0 ± 66.5	4.0 ± 4.0	5.0 ± 4.5	15.3 ± 7.8
Contrasts[a]						
Fenoxycarbs versus control	—	—	1.23	101.55**	138.77**	76.07**
Fenoxycarb–SBO versus fenoxycarb–NOSBO	—	—	0.70	0.00	0.45	0.24

[a] F values for contrasts determined to be significant (*, $P \leq 0.05$), highly significant (**, $P \leq 0.01$); otherwise, data not significant ($P \leq 0.05$; orthogonal comparisons using GLM [SAS Institute 1988]).

laboratory data were baits with soybean oil (SBO) versus baits without soybean (NOSBO), fenoxycarb–SBO and fenoxycarb–NOSBO versus control–SBO and control–NOSBO, and fenoxycarb–SBO versus fenoxycarb–NOSBO. For the field data, contrasts were fenoxycarb–SBO and fenoxycarb–NOSBO versus control (untreated), and fenoxycarb–SBO versus fenoxycarb–NOSBO.

Results and Discussion

Chemical analysis of the baits before application showed that active ingredient (AI) was 0.84 ± 0.01% ($\bar{x} \pm$ SE) in the fenoxycarb–SBO and 2.06 ± 0.02% in the fenoxycarb–NOSBO. All red imported fire ant laboratory colonies treated with the two fenoxycarb formulations died. As expected (Banks et al. 1988), colony effects included cessation of all worker brood production in 4–8 wk and production of large numbers of sexuals after 12–16 wk. Worker mortality occurred naturally with no significant difference after 21 wk between the two formulations of fenoxycarb (71.9% with NOSBO versus 62.5% with SBO). However, the difference between the fenoxycarb treatments and the controls was highly significant ($F = 31.41$; df = 1, 10; $P \leq 0.01$) (Table 1). The queens in colonies treated with the fenoxycarb–SBO bait died more quickly than those treated with the fenoxycarb–NOSBO bait (7 versus 15 wk). One reason may be that fenoxycarb in SBO moves through the colony food chain at a faster rate and therefore reaches the queen sooner. Although the mean percentage of fenoxycarb–NOSBO bait removed by the workers was greater than the amount of fenoxycarb–SBO bait (69.6 versus 50%), the difference was not significant. There was a significant difference ($F = 6.34$; df = 1, 10; $P \leq 0.05$) between the percentage of bait removed by the worker ants in the controls (SBO and NOSBO) and the fenoxycarb baits (SBO and NOSBO) (Table 1). Overall, it appeared that the addition of fenoxycarb to the formulations caused some repellency.

The application rate of fenoxycarb in the field tests was 9.41 g (AI)/ha for the SBO formulation and 23.1 g (AI)/ha for the NOSBO (Table 2). Red imported fire ant population indices (PI) did not differ significantly at any time during the 6-, 12-, and 18-wk field evaluations between the NOSBO and the SBO formulations of fenoxycarb (Table 2). The flowability and the dispersal of the NOSBO bait based on field observations was as good as or better than the standard bait. Also, clogging of the equipment, which sometimes results from adherence or compaction of SBO and grits in the auger applicator with standard bait, did not occur with the NOSBO bait.

The concentration of fenoxycarb as indicated by analysis was >2-fold greater (2.06 versus 0.84%) in the NOSBO bait. However, analysis of individual worker ants collected from plots treated with the fenoxycarb–NOSBO baits revealed that they contained >47-fold less concentration of fenoxycarb (2.0 ± 0.4 ng/mg ant [$\bar{x} \pm$ SD]) than workers in plots treated with fenoxycarb–SBO baits (93.6 ± 68.0 ng/mg ant). This difference could reflect a much greater availability of fenoxycarb to the worker ants when high levels of SBO are added to the grits, because the workers feed on liquids and not on the solid grit particle. This factor may have been reflected in the laboratory data by a slower death rate of the queens in colonies treated with the fenoxycarb–NOSBO bait. The difference also illustrates the effectiveness of extremely low levels of fenoxycarb, which undoubtedly accounts for the comparable reductions in the population indices of the field populations. Glancey et al. (1989) demonstrated excellent activity of fenoxycarb against laboratory colonies at dosages as low as 0.125 mg per colony. In field tests, Banks et al. (1988) showed that, although the range of amounts of fenoxycarb applied was quite large (6.20–25.05 g (AI)/ha), the mean reductions in population indices (68.8–99.1) were not significantly different.

Another possible benefit of the NOSBO formulation may be an increase in shelf life of the bait. Rancidity of soybean oil in baits is a problem because it reduces feeding on the bait (Lofgren et al. 1964a). Thus, its removal from a formulated bait would eliminate this factor and should increase shelf life. We do not have any evidence at present that there would be a problem with rancidity of the very small amount of residual oil remaining in the pregel defatted corn grit during its manufacture. Elimination of the SBO produces one definite benefit in a reduction in the cost. This cost reduction could be passed on to the users of the bait.

In conclusion, our data show that the NOSBO formulation for fenoxycarb was as effective as the SBO formulation against both laboratory colonies and field populations. However, our method of formulation resulted in a larger amount of active ingredient being applied with the NOSBO formulation. There is evidence that the amount of active ingredient in the fenoxycarb–NOSBO or the bulk rate of application can be reduced to a much lower level without affecting the efficacy. The removal of soybean oil from the bait formulation would improve the flowability, reduce cost, and should increase shelf life. This study indicates that further studies are warranted with fenoxycarb–NOSBO formulations and with other chemicals in formulations without soybean oil. Also, more important, the effect of baits without soybean oil on nontarget insects, especially other ant species, needs to be determined.

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