Effectiveness of the Insect Growth Regulator Pyriproxyfen Against the Red Imported Fire Ant (Hymenoptera: Formicidae[1])

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ABSTRACT The juvenoid pyriproxyfen (2-[1-Methyl-2-(4-phenoxyphenoxy) ethoxy] pyridine caused 80-85% reductions in the colony size index of laboratory colonies of the red imported fire ant, *Solenopsis invicta* Buren, within four weeks after treatment. All treated colonies continued to decline in size and died within 6-7 months after treatment. Corn grit-soybean oil baits contianing pyriproxyfen were as effective in four field tests as Logic, a JH-based bait widely used for fire ant control. The baits were slightly more effective in spring-summer than in fall, producing population index reductions of 91-97% and 72-88% respectively at 13 weeks after treatment.

KEY WORDS Red Imported fire ant, *Solenopsis invicta*, pyriproxyfen, insect growth regulator.

Some insect growth regulators (IGRs), primarily juvenile hormone mimics, are very active against the red imported fire ant (RIFA), *Solenopsis invicta* Buren, and can be effectively used to suppress field populations (Banks 1986, Banks and Harlan 1982, Banks et al. 1978, 1983, 1988, Phillips et al. 1985, Vinson and Robeau 1974, Vinson et al. 1974). The most effective IGRs prevent worker replacement in RIFA colonies through lethality to developing immatures, degeneration of the reproductive organs of the queen, and a shift in caste differentiation from worker to sexual forms. This lack of worker replacement usually results in colony death as the existing worker ants age and die. Large queenright laboratory colonies usually die within six to eight months after ingestion of 5.0 - 10.0 mg active ingredient (AI) of IGR.

Fenoxycarb is the most effective of ca. 90 IGRs tested against RIFA in our laboratories since 1974. A number of field tests have shown that rates of 6-20 g AI per ha in baits cause death of 85-100% of colonies in treated areas (Banks 1986, Banks et al. 1983, 1988, Phillips and Thorvilson 1989, H. L. Collins - personal communication). Fenoxycarb is currently marketed for fire ant control in the commerical bait Logic®.

The juvenoid pyriproxyfen (2-[1-Methyl-2-(4-phenoxyphenoxy) ethoxy] pyridine - Sumitomo S-31183) is active against the big-headed ant, *Pheidole megacephala* (F.) (Reimer et al. 1991), mosquitoes (Schaefer et al. 1988), and cockroaches (Koehler and Patterson 1991).

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In our ongoing laboratory program to evaluate additional IGR, we have determined that pyriproxyfen is also highly active against RIFA. We report here the results of laboratory and field studies with pyriproxyfen against RIFA.

Materials and Methods

Laboratory Tests. Technical pyriproxyfen incorporated at 2.0% by weight into once-refined soybean oil (ORSBO) was tested at 10 mg/colony, in two tests, against laboratory-reared colonies of RIFA. In each test, three colonies, each consisting of a queen, 10-40 ml immatures (eggs, larvae, and pupae), and 40,000-60,000 worker ants, were allowed ad libitum feeding on the oil solution (0.5 ml) that was offered to them in micropipets. Three control colonies were given an equivalent volume of neat ORSBO. The colonies were returned to the normal diet 24 h after treatment and held in the laboratory at 27 ± 2° C (Banks et al. 1981). Detailed observations to determine effects on the colonies were made biweekly through 16 weeks after treatment and monthly thereafter until the colonies died or through one year, whichever occurred first. Effectiveness of the treatments on the colonies was determined by statistical comparison of changes in the colony size indices (SAS Institute 1985). The colony index is derived by multiplication of assigned values for worker numbers and quantity of worker brood (see table below); e.g. a colony with 35,000-50,000 workers and > 30 ml of immatures would have a colony index of 125 (5 × 25).

Estimated number worker ants		Estimated quantity of worker brood (ml)	
	Value		Value
<100	1	0	1
101-5000	2	1-5	5
5001-20000	3	5-10	10
20001-35000	4	10-20	15
35001-50000	5	20-30	20
>50000	6	>30	25

Field Tests. Granular baits, composed of pregel defatted corn grits, ORSBO, and various concentrations of technical pyriproxyfen, were tested against natural infestations of RIFA in Polk Co., FL in 1985 and 1988, Union Co., FL in 1986, and Brooks Co., GA in 1987. The baits and rate of application for all tests are shown in Table 2. The baits were broadcast with a tractor-mounted granular applicator (Williams et al. 1983) on 0.3 ha plots in nongrazed permanent pasture. In each test, each treatment was applied to 3 plots; 3 plots were treated with Logic bait as a standard and 3 plots were left untreated as controls.

Efficacy of all the treatments was evaluated by comparing before and after treatment population indices. A standard method for determination of population indices of RIFA on field plots was described by Banks et al. (1988). With this method, all mounds on circular subplots (0.1 ha) established in the center of each larger plot are opened with a spade and the contents carefully examined before

treatment and at specified intervals after treatment. Each active IFA nest is then rated 1-25 based on the estimated number of worker ants and the presence or absence of worker brood. The rating is then used to calculate a population index by using the following scale:

Number of worker ants	nest index when worker brood is	
	absent	present
<100	1	5
100-1000	2	10
1000-10000	3	15
10000-50000	4	20
>50000	5	25

The population index for each subplot is obtained by summation of the index values for all mounds present at the time of evaluation. The population index for all treatments is obtained by summation of the indices for all subplots within the unit.

In this study, effectiveness of treatments was determined by comparison of before and after treatment indices. Data were analyzed using general linear models and mean reductions in population indices were compared with Duncan's multiple range test (SAS Institute 1985).

Results and Discussion

Laboratory Tests. Pyriproxyfen was very effective against the laboratory colonies of RIFA in both tests (Table 1). Observations showed that after two wk the quantity of worker brood was reduced in all treated colonies, and the presence of some sexual brood indicated that a shift in caste differentiation had begun. Treatments reduced the mean size index of colonies by 80-85% after 1 month and by about 96% after 2 months. Colony death occurred by 5 months in one replicate and by 6 months after treatment in the other two replicates in test one. All colonies in test two were dead seven months after treatment. Colony indices of the untreated controls in test one fluctuated, but generally increased during the test period. The reduction in mean colony indices for the checks in test two resulted from a cessation of brood production and a decline in the size of one colony; the other two check colonies remained constant or increased in size.

Field Tests. Baits containing pyriproxyfen were equal in effectiveness to the Logic standard in all four tests against field populations of RIFA (Table 2). There was no significant effect of IGR concentration in the bait nor of rate of application of either bulk bait or active ingredient in any test. In three of the four tests, efficacy was slightly reduced, although not significantly so at the lowest rate of the least concentrated formulation. Although data are insufficient for definite conclusions, the results suggest that effectiveness may be influenced by time of year that treatments are made. Population index reduction with both the pyriproxyfen bait and the Logic standard was highest in the two tests conducted during the spring and summer (tests 1 and 3), ranging from ca. 91 to 98% after 13 wk. By contrast, mean population index reduction for tests begun late summer and fall (tests 2 and 4) was 10-15% lower. We suspect that cooler temperatures during the test may have reduced efficacy. We found in previous tests that toxicants or IGRs applied

Table 1. Effects of pyriproxyfen on laboratory colonies of red imported fire ants (mean from 3 colonies per test, 10 mg AI per colony).

Colonies	Mean colony index before treatment*	Mean percent reduction in colony index after indicated months†				
		1	2	4	6	7
		Test 1				
Treated	133.3	80.0 a	96.5 a	96.5 a	100 a	
Control	100	11.7 b	+3.3 b	5.0 b	+1.3 b	
		Test 2				
Treated	141.7	84.7 a	96.5 a	98.4 a	99.0 a	100 a
Control	133.3	0 b	30.0 b	24.3 b	24.3 b	24.5 b

* See text for method of determining colony index.

† Plus sign indicates increase in colony index. Means within a column followed by the same letter are not significantly different (P = 0.05 Duncan's multiple range test [SAS Institute 1985].

in late fall or early winter exert effects on the ants more slowly and generally the overall effect is less than with spring or summer treatments (Lofgren et al. 1964, Banks et al. 1971, 1972, 1988).

Within six weeks after RIFA queens ingest pyriproxyfen the ovarioles become vacuolated, the tunica propria thickened, and most eggs are resorbed (Glancey et al. 1990). These effects appear to be reversible, however, if the IGR is eliminated by metabolism or excretion. Queens collected from treated field colonies at six weeks posttreatment exhibited these effects. However, queens collected from other colonies within the same plot at 24 weeks, when effects of the IGR were no longer apparent, had normal ovaries and a full complement of eggs within the ovarioles. Although we have not studied effects of a second application of pyriproxyfen after 12-16 wk, we hypothesize that retreatment might maintain a sufficient titer of IGR to prevent recovery of egg-laying capability by the queens.

Results of our laboratory and field tests indicate that pyriproxyfen will effectively suppress populations of RIFA and should give control comparable to that produced by Logic.

Table 2. Effects of pyriproxyfen baits on field populations of red imported fire ants (mean from 3 replications at each rate).

IGR Conc. in bait	Application rate		Before treatment		mean % reduction in population index after indicated weeks†			
	bait (kg/ha)	AI (g/ha)	No. active nests	Pop'n index	6	13	20	26
			Test 1					
0.5	1.05	5.26	27	650	88.4 a	97.7 a		
	2.1	10.52	25	596	91.9 a	97.1 a		
1.0	1.17	11.70	25	554	90.8 a	96.2 a		
	2.34	23.40	25	593	85.7 a	96.9 a		
Logic (std) 1.0	1.22	12.18	31	731	90.3 a	97.5 a		
Untreated control			27	612	27.3 b	25.0 b		
			Test 2					
0.5	1.12	5.60	22	515	84.8 a	82.3 a		
	2.24	11.20	22	472	82.6 a	86.9 a		
1.0	1.22	12.24	24	555	80.1 a	87.9 a		
	2.44	24.48	23	494	83.7 a	88.4 a		
Logic (std) 1.0	1.69	16.95	25	538	78.0 a	90.2 a		
Untreated control			27	552	+34.0 b	+41.5 b		

Table 2. Continued.

IGR Conc. in bait	Application rate		Before treatment		mean % reduction in population index after indicated weeks†			
	bait (kg/ha)	AI (g/ha)	No. active nests	Pop'n index	6	13	20	26
			Test 3‡					
1.0	1.10	11.00	38	806	84.5 a	91.2 b	91.7 a	
	2.20	22.01	35	715	83.1 a	95.4 a	93.0 a	
Logic (std)								
1.0	1.13	11.29	41	855	84.5 a	97.6 a	92.3 a	
Untreated control			30	657	16.0 b	21.8 c	28.2 b	
			Test 4					
0.75	1.16	8.71	26	537	67.4 a	71.7 a	77.9 a	80.5 a
1.5	1.00	15.06	35	790	74.9 a	76.8 a	83.8 a	85.9 a
Logic (std)								
1.0	1.00	10.04	35	765	80.2 a	83.5 a	86.4 a	85.9 a
Untreated control			32	705	+74.1 b	+77.6 b	+70.4 b	79.1 b

* Baits composed of pregel defatted corn grits - 70%, IGR at indicated concentration plus once-refined soybean oil - 30%.

† Means within a column followed by the same letter are not significantly different (P = 0.05 Duncan's multiple range test, [SAS Institute 1985]). Means preceded by a plus represent an increase in the population index.

‡ Third evaluation in test 3 made at 17 wk rather than 20.

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