THE RED IMPORTED FIRE ANT, *SOLENOPSIS INVICTA*:[1] CONTROL WITH FLUOROALIPHATIC SULFONE BAIT TOXICAN'

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Abstract: Five of twelve fluoroaliphatic sulfones tested in baits against laboratory colonie *Solenopsis invicta* caused 80% worker mortality within 20 days; with one exception. compounds caused death of the queen within 46 days. In field tests conducted in Geo and Florida, several of these compounds were as effective as the Amdro standard.

Key Words: Imported fire ant, *Solenopsis invicta*, fluoroaliphatic sulfones, chemical b toxicants, delayed activity.

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The red imported fire ant (RIFA), *Solenopsis invicta* Buren, is a major pest spe that has been the target of control programs involving chemical baits since early 1960s (Lofgren et al. 1963, 1964; Banks et al. 1973; Alley 1973; Harlan et 1981). Mirex bait was the chemical control method of choice from 1962 thro 1977 at which time its registrations were cancelled by the Environmental Protect Agency (Johnson 1976). This action initiated an intensive effort by ARS-USDA find other chemical toxicants, as well as insect growth regulators, and reproduct inhibitors for use in baits against fire ants (Lofgren 1986). Requirements for l toxicants are strict because the chemical must: 1) exhibit delayed toxicity, 2) effective over an extended dosage range, 3) not be repellent to ants, 4) formul with carriers easily, and 5) be environmentally acceptable (Stringer et al. 19 Banks et al. 1977; Williams 1983). Of the more than 7000 chemicals tested as l toxicants since 1958, only mirex, hydramethylnon known as Amdro (Ameri Cyanamid Company; Williams et al. 1980), 1-(8-methoxy-4,8-dimethylnonyl)-4 methylethyl) benzene called Pro-Drone (Stauffer Chemical Company), fenoxyc which is called Logic (Maag Agrochemicals, Inc.), and abamectin known Affirm (Merck, Sharp & Dohme Research Laboratories) have been develo commercially.

Vander Meer et al. (1985) reported the discovery of a new class of dela action insecticides, fluoroaliphatic sulfones, that showed promise against fire a in addition to other insect pests. They demonstrated that the heptadecafluoro radical yielded the best delayed activity and both the fluorocarbon and sulf groups were essential to the activity. Tests with 54 fluorinated sulfonamides sulfonic acids showed the prerequisite delayed toxicity essential for effectiven against RIFA. Several promising chemicals from these initial screening tests w selected for secondary laboratory screening tests.

This paper reports on bait toxicant studies with a new class of insectici fluoroaliphatic sulfones, against laboratory colonies and field populations of RIF

[1] HYMENOPTERA: Formicidae.

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MATERIALS AND METHODS

The procedures used were similar to those described by Williams (1983). All laboratory colonies were 10 - 20 months old and consisted of a queen (monogynous), eggs, larvae, and pupae and ca. 40,000 workers. They were reared according to methods described by Banks et al. (1981) except they were maintained on a diet of honey-water, hard-boiled chicken eggs, and house fly pupae. Food was withheld for 5 days prior to the test. The test chemicals were dissolved at 1.0% w/w in once-refined soybean oil which was absorbed on pregel defatted corn grits (Lauhoff Grain Company, Danville, IL). Ants were allowed to feed (*ad lib.*) on the bait (5 g) for 2 - 3 days after which any bait remaining was removed and replaced with the standard diet. Observations were made on the status of the queen, brood, and workers for 44 - 46 days or until the queen, brood, and > 90% of the workers were dead (whichever came first). Each chemical was tested against four laboratory colonies. Check colonies were fed the bait formulation without the toxicant and monitored along with treated colonies.

Field assays were conducted in Florida and Georgia. All chemicals were dissolved in once-refined soybean oil (SBO) at concentrations of 1.0 - 2.5% (w/w). The oil solution was absorbed onto pregel defatted corn grits 30% by weight of total formulation to yield baits containing 0.30, 0.60, or 0.75% active ingredient (AI). All baits were applied with a tractor-mounted auger applicator (Williams et al. 1983) at 3.3, 4.9, or 8.1 g AI/ha. Amdro fire ant bait (0.88% AI) was applied at the label recommendation rate of 10.4 g AI/ha. All treatments were applied to 0.4 ha plots except those in Brooks County, GA, which were on 1.2 ha plots. Plots were located in non-grazed permanent pastures (Lake City, FL, and Brooks County, GA) or vacant land in an industrial park (Homerville, GA). Each treatment was replicated 3 times. Pre and posttreatment counts of active nests were made on a 0.2 ha circle in the center of each of the 0.4 ha plots; in the Brooks County, GA, test control was monitored on three 0.2 ha circles in each of the 1.2 ha plots. Each nest was evaluated by estimating the number of workers and the presence or absence of worker brood. Pretreatment and posttreatment evaluations were made at 6 and 12 wk using a population index system devised by Harlan et al. (1981) as modified by Lofgren and Williams (1982). Thus, each colony was rated on its size (no. of worker ants ranging from < 100 workers to > 50,000) and presence (normal) or absence (abnormal) of worker brood. From this information, each colony was assigned a rating (1 - 25). The total of the ratings for the colonies in each plot was the "population index" (PI) for that plot. The pre and posttreatment population indexes were used to calculate the percent control. Untreated plots similar in size to treated plots were monitored as controls.

Data were analyzed by using general linear models (GLM) in SAS (Statistical Analysis Institute, Inc., Cary, NC 27511, 79.5 version) with percent reduction as the dependent variable. Duncan's multiple range test was used to compare means for each treatment.

RESULTS AND DISCUSSION

Acceptance (= bait removal from dish) of the SBO laboratory control oil bait averaged 98%. Acceptance of three of the chemical baits (10709, 10733, 29778) ranged from 53 to 70%, while acceptance of the remainder varied from 16 to 39%.

Whether this variability represents true repellency of the chemicals or the ef
impurities is not known. Despite this variation in bait acceptance, 5 of
fluoroaliphatic sulfones caused > 80% kill of the workers within 20 days (Ta
and 10 gave over 90% kill within 34 days. With one exception, the comp
killed the queens from the 4 replicates (4 colonies with 1 queen per colony)
46 days. In one of the colonies treated with 10714, the surviving queen
produced viable eggs and only 450 workers remained when the test was term
after 46 days. Reduction in brood numbers after 2 weeks posttreatment ave
from 24 to 91%; however this variation is not necessarily significant beca
could represent mortality, development of larvae and brood to the adult sta
both.

All of the compounds produced good delayed kill ranging from 1 to 24% a
to 3 days. Queen mortality occurred faster with 10702 and 29778 (< 20
however our general observations revealed that the queens in all of the tests
either sick or dead by 21 days and in most cases within 7 to 14 days.

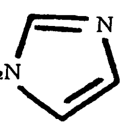
The laboratory colony results showed that all the compounds warranted
tests; however, these tests are expensive, time consuming and labor inte
Other factors important to eventual commercialization such as oil solubility
acceptance, and availability were considered. Compound 29778 was not
soluble in soybean oil and the actual amount available to the test colonie
uncertain. Although worker mortality was not monitored beyond 16 - 20
29778 showed the lowest worker mortality of all the compounds tested fo
time period. Fluorosulfonamide 10714 did not kill all of the queens in the
replicates and was not field tested. The remaining ten toxicants were tested
the following three tests.

Field assays were initiated in July, 1982, in Lake City, FL, using comp
29757, 29758, and 29759. Prior solubility tests indicated that two of the chem
29757 and 29758, were not completely soluble at the desired concentration of
therefore, they were tested only at 1.0% in the soybean oil while 29759 was t
at two concentrations, 1.0% and 2.5%. The results of these tests (Table 2) di
indicate a significant difference (P > 0.05) between any of the three chemical
the Amdro standard at the 6 or 12 week posttreatment period. Also, there w
significant difference between the two concentrations of 29759.

The second set of tests was conducted in Homerville, GA, in April, 1983. '
compounds previously tested and five additional compounds (10702, 10707, 1
10712, and 10733) were evaluated. No significant differences (P > 0.05) in pe
reduction in the population indices at 6 wk posttreatment were noted with 2
29759, 10702, 10733, and Amdro (std.) although the mean percent reduc
ranged from 60 to 81%. The remaining compounds gave less than 50% contro
results are reported 12 wk posttreatment in this test series because s
reductions in the PI of the control plots caused by very heavy rains resulted
significant differences (P > 0.05) between any of the treatments and
control.

The third in Brooks County, GA, (May, 1984) involved four chemicals, tw
which (10709 and 10717) had not been field tested before. Even though comp
10710 gave poor control in the Homerville test, it was retested because it
readily soluble in soybean oil, and was reported to be highly active against
cutting ants (Febvay et al. 1985). Compound 29757 was tested again because i
given consistently good results in the two prior field tests and because

Table 1. Toxicity of baits containing several fluoroaliphatic sulfones to workers and queens in four monogynous laboratory colonies of the red imported fire ant.†

Chemical (AI3-No.)	Structure	Mean worker mortality (%) and queen mortality(*) at indicated days posttreatment‡ 2 - 3	9 - 10	16 - 20	23 - 27	32 - 34	44 - 46
10702	$C_6F_{13}SO_2NH_2$	18	65	90****			
10707	$C_8F_{17}SO_2N(C_2H_5)_2$	4	71	91***	95	99.9*	
10709	$C_8F_{17}SO_2\overset{C_2H_5}{N}CH_2C\equiv CH$	1	26	63	79	96**	99.9**
10710	$\underline{n}$-$C_8F_{17}SO_2\overset{H}{N}CH_2CH=CH_2$	1**	60	80	94	99**	
10712	$C_8F_{17}SO_2\overset{H}{N}CH(CH_3)_2$	10	38	84*	93*	98*	99*
10714	$\underline{n}$-$C_8F_{17}SO_2\overset{H}{N}C_6H_5$ (recrystalized linear isomer)	24	38	51	77	84**	97*
10717	$C_8F_{17}SO_2\overset{CH_3}{N}CH=CH_2$	19	39*	67	80*	94*	99.9*
10733	$C_8F_{17}SO_2NC_2H_4Cl$	8	53	81	94***	99.9*	
29757	$C_8F_{17}SO_2\overset{H}{N}C_2H_5$	13	44	71*	97***		
29758	$C_8F_{17}SO_2\overset{H}{N}CH_3$	4	28	46**	90*	92*	
29759	$C_8F_{17}SO_2NH_2$	7	35	46*	68	78*	97**
29778	$C_8F_{17}SO_2N$ 	0	9*	25***			
Control§		0	1	2	2	3	3

† Five grams of bait offered to each colony; bait consisted of 1.5 g soybean oil containing 1% toxicant and toxicant applied on 3.5 g of pregel defatted corn grits; four colonies per treatment.
‡ Each asterisk (*) denotes death of a colony queen; e.g., for AI3-10707, the queen in three colonies died 16-20 days after exposure while the queen in the 4th colony died after 32-34 days; colonies were presumed dead and discarded when queen expired, thus worker mortality shown represents only that for colonies with a surviving queen.
§ Bait without toxicant; six colonies/treatment.

Table 2. Effects of granular soybean oil baits containing fluoroaliphatic su on field populations of the red imported fire ant in Florid Georgia.*

Chemical (AI3-No.)	Toxicant conc. (%) w/w in SBO	Rate g (AI)/ha	Mean reduction (' population inde: weeks indicate 6	1
Lake City, FL, July, 1982				
29758	1.0	3.3	99a	84
29759	2.5	8.1	95a	91
29757	1.0	3.3	83a	7:
25759	1.0	3.3	81a	7£
Amdro (std.)	2.5	10.4	93a	91
Control	—	—	0b	0
Homerville, GA, April, 1983				
29757‡	1.0	3.3	81a	
25759	1.0	3.3	80a	
10702	1.0	3.3	75ab	
10733‡	1.0	3.3	60abc	
10712	1.0	3.3	49bcd	
29758	1.0	3.3	40dce	
10710	1.0	3.3	30de	
10707	1.0	3.3	30de	
Amdro (std.)	2.5	10.4	79a	
Control§	—	—	16e	
Brooks County, GA, May, 1984				
10710	2.5	3.3	98a	87
29757	2.0	4.9	94a	86
29757	1.0	3.3	92a	87
10709	2.5	3.3	82bc	82
10717	2.5	3.3	75c	90
Amdro (std.)	2.5	10.4	91ab	94
Control	—	—	4d	51

* Bait consisted of 70% pregel defatted corn grits impregnated with 30% of the soybean oil-t solution. Application rate of the formulation was 2.2 kg/ha. Mean of three treated and contro unless indicated otherwise.
† Data corrected with Abbott's formula for check mortality. Means within columns followed by th letter are not significantly different at the P > 0.05 level of confidence based on Duncan's m range test.
‡ Mean of two plots.
§ Mean of four plots, all other controls avg. of three plots.

containing this compound appeared more acceptable (i.e., less repellent) t ants in laboratory bait acceptance tests (C.S. Lofgren et al., unpublished The data in these tests (Table 2) demonstrated again that 29757 was very effe against RIFA being equal to the Amdro standard at both concentrations teste significant differences (P > 0.05) occurred between the two concentrations (1.

2.0%) of 29757 in this test. Compound 10710 was also as good as the Amdro standard at 6 wk posttreatment evaluation. At 12 wk, all of the compounds were equally effective ($P > 0.05$).

Our data demonstrate that several of the fluoroaliphatic sulfones may be suitable as bait-toxicants for control of the RIFA since they meet four of the five criteria established by Williams (1983) as listed in the introduction of this paper. Their delayed-action and their activity against other insects (Vander Meer et al. 1983) suggest that further study of these chemicals to assess their potential for controlling other pest ants and insects is warranted. Finally, Griffin Corporation of Valdosta, GA, has been licensed by the U. S. Department of Commerce to develop these compounds commercially as fire ant toxicants. After assessing all biological data and availability of compounds, Griffin Corporation decided to commercialize compound 29757.

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REFERENCES CITED

Alley, E. G. 1973. The use of mirex in control of the imported fire ant. J. Environ. Qual. 2: 52-61.

Banks, W. A., B. M. Glancey, C. E. Stringer, D. P. Jouvenaz, C. S. Lofgren, and D. E. Weidhaas. 1973. Imported fire ants: Eradication trials with mirex bait. J. Econ. Entomol. 66: 785-789.

Banks, W. A., C. S. Lofgren, D. P. Jouvenaz, C. E. Stringer, P. M. Bishop, D. F. Williams, D. P. Wojcik, and B. M. Glancey. 1981. Techniques for collecting, rearing, and handling imported fire ants. U. S. Dep. Agric., Sci. Ed. Admin., AAT-S-21: 1-9.

Banks, W. A., C. S. Lofgren, C. E. Stringer, and R. Levy. 1977. Laboratory and field evaluation of several organochlorine and organophosphorus compounds for control of imported fire ants. USDA, ARS, (Ser.) ARS-S-169, 13 pp.

Febvay, G., B. Hostachy, and A. Kermarrec. 1985. La lutte chimique contra la fourmi *Acromyrmex octospinosus* (Reich): Test standardise d'evaluation de L'effet retard de matieres actives et nouvelle strategie de lutte. Med. Fac. Landbouww. Rijksuniv. Gent. 50/2b: 723-734.

Harlan, D. P., W. A. Banks, H. L. Collins, and C. E. Stringer. 1981. Large area tests of AC-217,300 bait for control of imported fire ants in Alabama, Louisiana, and Texas. Southwest. Entomol. 6: 150-157.

Johnson, E. L. 1976. Administrator's decision to accept plan of Mississippi Authority and order unpending hearing for the pesticide chemical mirex. Fed. Reg. 41: 56694-56704.

Lofgren, C. S. 1986. History of the imported fire ant problem, pp. 36-47. *In* C. S. Lofgren, and R. K. Vander Meer [eds.], Fire Ants and Leaf Cutting Ants: Biology and Management. Westview Press, Boulder, CO. 435 pp.

Lofgren, C. S., F. J. Bartlett, and C. E. Stringer. 1963. Imported fire ant toxic bait studies: Evaluation of carriers for oil baits. J. Econ. Entomol. 56: 62-66.

Lofgren, C. S., F. J. Bartlett, C. E. Stringer, Jr., and W. A. Banks. 1964. Imported fire ant toxic bait studies: Further tests with granulated mirex-soybean oil bait. J. Econ. Entomol. 57: 695-698.

Lofgren, C. S., and D. F. Williams. 1982. Avermectin B_{1a}: Highly potent inhibitor of reproduction by queens of the red imported fire ant (Hymenoptera: Formicidae). J. Econ. Entomol. 75: 798-803.

Stringer, C. E., Jr., C. S. Lofgren, and F. J. Bartlett. 1964. Imported fire ant tox studies: Evaluation of toxicants. J. Econ. Entomol. 57: 941-945.

Vander Meer, R. K., C. S. Lofgren, and D. F. Williams. 1983. A method for control of i U. S. Patent Application SN 455,727.

Vander Meer, R. K., C. S. Lofgren, and D. F. Williams. 1985. Fluoroaliphatic sulfones: class of delayed-action insecticides for control of *Solenopsis invicta* (Hymen Formicidae). J. Econ. Entomol. 78: 1190-1197.

Williams, D. F. 1983. The development of toxic baits for the control of the imported fi Florida Entomol. 66: 162-172.

Williams, D. F., C. S. Lofgren, W. A. Banks, C. E. Stringer, and J. K. Plumley. Laboratory studies with nine amidinohydrazones, a promising new class of bait to for control of red imported fire ants. J. Econ. Entomol. 73: 798-802.

Williams, D. F., C. S. Lofgren, J. K. Plumley, and D. M. Hicks. 1983. Auger-applicat applying small amounts of granular presticides. J. Econ. Entomol. 76: 395-397.