Effectiveness of Spot Insecticide Treatments for Red Imported Fire Ant (Hymenoptera: Formicidae) Control[1,2]

Homer L. Collins and Anne-Marie A. Callcott

U. S. Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine
Imported Fire Ant Station
Gulfport, MS 39501 U.S.A.

J. Entomol. Sci. 30(4): 489-496 (October 1995)

ABSTRACT Spot treatments with Dursban 2EC, Optem PT-600, Bengal Fire Ant Killer, and Orthene 75S were evaluated for control of imported fire ant, *Solenopsis invicta* Buren, colonies. Because imported fire ant colonies frequently relocate their nest following insecticide applications, a field trial utilizing an experimental design which compensated for colony relocation was conducted. Results of this trial showed that, in addition to frequent colony relocation, large numbers of individual ants succumbed to several of the insecticides under trial. However, many ant colonies survived some treatments, and actual colony mortality ranged from 11.1% with Orthene 75S to 80.4% with Dursban 2EC 8 wks after treatment.

KEY WORDS Red imported fire ant, ant mound treatments, chemical control

Efforts to control imported fire ants, *Solenopsis invicta* Buren or *S. richteri* Forel, through spot treatments or individual mound applications of insecticides date back to 1937 when the first organized control program in Baldwin Co., AL was initiated. In that program, 48% calcium cyanide dust was applied to each nest by digging into the mound with a shovel, sprinkling the dust, and covering it with soil (Eden and Arant 1949). Even today, a number of commonly used insecticides, including acephate, bendiocarb, carbaryl, chlorpyrifos, diazinon, malathion, and many others are registered and marketed as liquid drenches, dusts, granules, and aerosols for spot treatment of fire ant nests. The literature is replete with reports of insecticide trials in which the authors used spot treatments or individual nest applications to evaluate the efficacy of candidate pesticides, formulations, or dose rates. Virtually all of the many trials conducted utilized various methods of marking treated mounds by tagging, flagging and/or mapping. Many studies used very small plots with or without buffer zones or various size boundaries around treated nests. However, imported fire ant colony

[1] Accepted for publication 21 June 1995.

[2] Mention of companies or commercial products does not imply recommendation or endorsement by USDA over others not mentioned. USDA neither guarantees nor warrants the standard of any product mentioned. Product names are used solely to report factually on available data and to provide specific information.

movement or nest relocation in response to insecticidal treatment is a well-documented phenomenon (Hays et al. 1982, Franke 1983, Williams and Lofgren 1983, Collins et al. 1992). This induced movement due to the presence of an insecticide is usually over a relatively short distance (1.5 to 3 m), but can be greater (personal observation). Colony movement or relocation in field trials based on marked colonies or small plots can skew results when mortality data are based solely on survival of marked or tagged mounds, or in trials in which relatively small plots are used. We report here the results of a field trial that utilized an experimental design which compensated for colony relocation following insecticide application to individual fire ant mounds.

Materials and Methods

Test plots measuring 64 × 64 m (0.4 ha or 1 acre) were established in Harrison Co., MS on 03 November 1993 in an area infested with a monogynous imported fire ant population averaging 223.25 active mounds/ha. An experienced team of six investigators closely searched each entire test plot and flagged each active imported fire ant mound immediately prior to pesticide application, thereby insuring that each mound in each test plot was treated.

Prior to treatment, circular subplots with a radius of 17.9 m (0.1 ha or 0.25 acre) were established in the center of each test plot (Fig. 1). Imported fire ant population estimates were made in each circular subplot prior to and 1, 2, 4, and 8 wks after pesticide application, using the population indexing system described by Harlan et al. (1981) and modified by Lofgren and Williams (1982) (Table 1). This system is based on the estimated population of worker ants and the presence or absence of worker brood (larvae and pupae). Absence of worker brood suggests that a colony does not contain a normally functioning queen. A newly-formed colony with worker brood present and less than 100 workers is numerically weighted as a "5" (colony class 6). Colonies of this rating are not easily visible in the field due to their very small mound size and, thus, rarely are detected. A large mature colony with worker brood and more than 50,000 workers is assigned a weighting factor of "25" (colony class 10). The population index for a particular site is calculated as follows:

$$\text{Population Index (PI)} = \sum_{K=1}^{25} \boldsymbol{K}\,(\boldsymbol{N}_k),$$

where N_k = the number of imported fire ant colonies in a given plot with a weighting factor of K where ($25 \geq K \geq 1$). The number of active imported fire ant mounds (≥ 20 workers) and population indices were calculated for each subplot. Untreated check plots were not treated in any manner, but were evaluated using the population estimation method previously described. These data were used to determine: 1) colony mortality, which is the percent decrease in pretreatment number of active mounds at each assessment interval, and 2) percent change in pretreatment population indices at each assessment interval. Means of each treatment were separated using ANOVA and a LSD test (SPSS Inc. 1992).

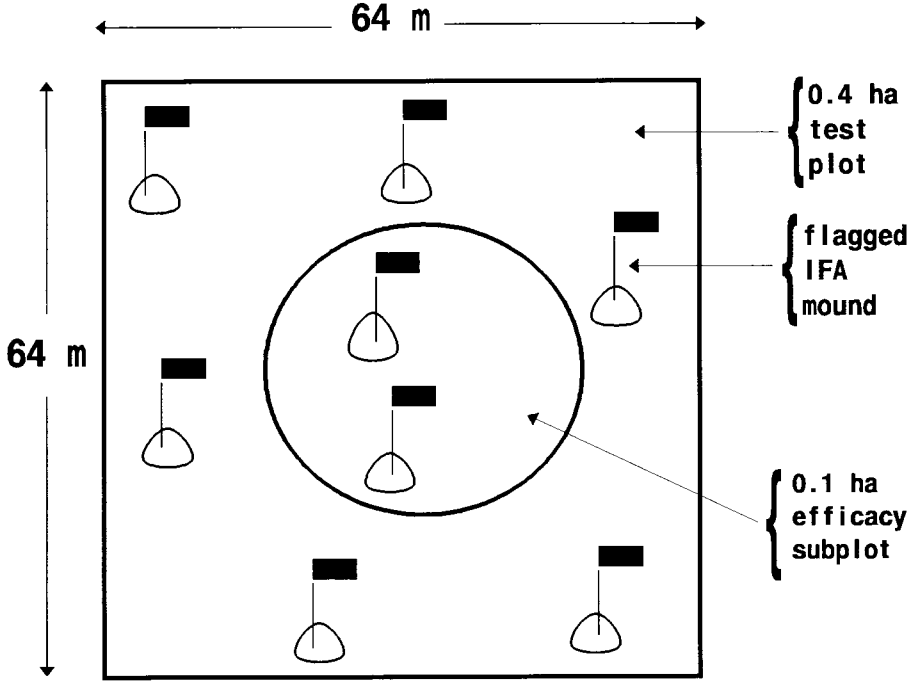

Fig. 1. Experimental design of field plots showing flagged imported fire ant mounds prior to pesticide application.

Table 1. Colony classification system used to evaluate the effects of insecticides on imported fire ant populations.

	Worker brood absent		Worker brood present	
Number of worker ants	Colony class	Weighting factor	Colony class	Weighting factor
< 100	1	1	6	5
100 - 1,000	2	2	7	10
1,000 - 10,000	3	3	8	15
10,000 - 50,000	4	4	9	20
> 50,000	5	5	10	25

Products tested included Dursban® 2EC [chlorpyrifos] (Rigo Company, Buckner, KY), Orthene® 75S [acephate] (Valent U. S. A. Corp., Walnut Creek, CA), Optem® PT-600 [cyfluthrin] (Whitmire Research Labs, St. Louis, MO), and Bengal® Fire Ant Killer Concentrate [(1R,3S)3[(1'RS)(1' ,2' ,2' ,2'-tetrabromoethyl)]-2,2-dimethylcyclopropanecarboxylic acid, (S)-alpha-cyano-3-phenoxybenzyl ester] (Bengal Chemical, Inc., Baton Rouge, LA). Dursban, Orthene, and Bengal Fire Ant Killer are registered for control of fire ants, and were applied according to label directions. Optem PT-600 is not registered specifically for fire ant control, but is registered for general outdoor ant control, and was applied at the highest labelled rate. Application rates, formulations, and methods of application are listed in Table 2.

Table 2. Insecticides evaluated as spot treatments for control of imported fire ant colonies.

Insecticide & Formulation	Method of Application	Rate of Application	
		Amount	g AI/mound
Dursban 2EC	Drench	0.5 oz/gal H_20/nest	3.54
Bengal Fire Ant Killer	Drench	0.2 oz/pt H_20/nest	0.24
Orthene 75S	Sprinkled on mound surface dry	2 tsp/nest	0.54
Optem PT-600	Drench	2.0 oz/gal H_20/nest	3.54

Results

Visual observations made 1 wk after treatment indicated that, with the exception of Orthene 75S, all insecticides killed large numbers of worker ants, and all surviving colonies were much reduced in size relative to the pretreatment population. All mounds which received a drench treatment (as evidenced by disrupted nest tumulus due to the effects of the drenching operation), were vacant, indicating that the colony had either succumbed to the treatment or had relocated the nest. Numerous freshly-formed nests, much smaller in size were usually observed within 1-2.5 m of the treated nest, indicating that colony relocation had occurred.

Dursban 2EC, Optem PT-600 and Bengal Fire Ant Killer provided the greatest control of imported fire ant field populations 2 wks after treatment by reducing the pretreatment population indices 86.4, 81.5, and 81.7%, respectively (Table 3). Compared to the corresponding untreated check, Dursban, Optem, and Bengal Fire Ant Killer significantly reduced the pretreatment population indices at each

Table 3. Reduction in pretreatment imported fire ant population indices by spot treatments with various insecticides, Harrison County, MS. November, 1993.

Treatment	% change in imported fire ant pretreatment population index at indicated wks posttreatment*			
	(1)	(2)	(4)	(8)
Dursban 2EC	-78.4 a	-86.4 a	-62.4 a	-83.4 a
Optem PT-600	-73.5 a	-81.5 a	-54.7 a	-61.7 a
Bengal Fire Ant Killer	-57.3 a	-81.7 a	-69.5 a	-61.1 a
Orthene 75S	-27.9 b	-30.3 b	-17.5 b	-11.5 b
Untreated Check	-25.2 b	-39.2 b	-16.2 b	-11.8 b

* Mean based on three replicates. Means within a column followed by the same letter are not significantly different (LSD Test, $P = 0.05$).

posttreatment rating interval. Orthene 75S was far less effective than Dursban, Optem, and Bengal Fire Ant Killer, and was not significantly different from the untreated check at any posttreatment rating interval.

Dursban achieved the greatest colony mortality at 2 and 8 wks after treatment, providing decreases of 79.4 and 80.4%, respectively (Table 4). Optem reduced the number of active mounds present by 78.7% at 2 wks posttreatment. Dursban and Optem also provided significantly greater colony mortality at each posttreatment interval compared to that of the corresponding untreated check. Bengal Fire Ant Killer caused variable colony mortality at 1 and 2 wks posttreatment, but was significantly better than the untreated check at 4 and 8 wks posttreatment.

Dursban, while not significantly more effective than Optem or Bengal Fire Ant Killer (except in colony mortality at 8 wks posttreatment), was numerically more effective, affording both greater population index reduction and colony mortality. This product was applied at a rate of > 14 times the rate of Bengal and > 6 times the rate of Orthene.

Discussion

Within all imported fire ant colonies, workers perform various tasks including brood tending, colony maintenance and defense, and foraging (Vinson and Sorensen 1986). Foragers, which include 20-60% of the workers (Mirenda and Vinson 1981), search for food outside the nest. Therefore, not all imported fire ant workers are present in the nest at the time of a drench application. Also, the internal structure of imported fire ant nests can impede the efficacy of drench

Table 4. Imported fire ant colony mortality produced by spot treatments with various insecticides, Harrison County, MS. November 1993.

Treatment	% decrease in pretreatment number of active imported fire ant colonies at indicated weeks posttreatment*			
	(1)	(2)	(4)	(8)
Dursban 2EC	68.7 a	79.4 a	52.5 a	80.4 a
Optem PT-600	70.4 a	78.7 a	51.4 a	57.2 b
Bengal Fire Ant Killer	42.9 ab	64.4 ab	53.0 a	40.6 b
Orthene 75S	16.5 b	23.9 c	2.0 b	11.1 c
Untreated Check	21.2 b	40.0 bc	10.3 b	10.0 c

* Mean based on three replicates. Means within a column followed by the same letter are not significantly different (LSD Test, $P = 0.05$).

applications. Large, mature imported fire ant nests can extend 60 cm under the surface of the soil, and can have additional tunnels which extend another meter or more to the water table (Markin et al. 1973). Therefore, it is unlikely that a one-gallon drench application, much less a one-pint application, could adequately penetrate and saturate the entire nest area and contact all members of an imported fire ant colony. The general decline in control from the 2 wk to 8 wk posttreatment count, as evidenced by both the population index data and the colony mortality data with Optem and Bengal Fire Ant Killer, cannot be explained by reinfestation of the test plots by newly-mated queens due to length of time required for colony growth and establishment (Markin et al. 1973, Callcott and Collins 1992), and was probably not due to invasion of the plot by untreated colonies immigrating from outside the plot due to the 14.2 m buffer provided by the plot design. More likely, colonies which were at first severely disrupted and decimated by the pesticide application were able to regroup and reform more visible nests 8 wks posttreatment.

Recent isolated infestations in Virginia, Tennessee, Arkansas, North Carolina, and other states outside the generally infested area have led to renewed efforts to eradicate small, incipient imported fire ant infestations to prevent further spread. These eradication efforts generally are conducted by the affected state plant regulatory agencies. Spot treatments alone or in combination with broadcast bait applications are commonly used in these programs, and success of the eradication effort is dependent upon judicious use of the most effective insecticides available. This study showed that 3 of the 4 candidate treatments provided less than 60% imported fire ant colony mortality at 8 wks posttreatment. These results should,

therefore, aid in the selection of the most appropriate products for small scale eradication efforts, or other fire ant control programs. These results also clearly demonstrate the need to use spot treatments in combination with other means of population suppression such as broadcast bait applications to achieve maximum control, because no spot treatment alone caused 100% colony mortality.

The experimental plot design used in this trial was extremely labor intensive, requiring approximately 100 person hours to lay out plots, conduct pre and post-treatment population estimates, and apply treatments. This extensive time frame was necessary to compensate for the effects of colony relocation due to insecticidal application. Investigators who treat a specific number of marked mounds and evaluate those mounds for imported fire ant activity, may confuse colony relocation with colony mortality, as many who used this method noted in their discussions (Gardner 1980, Marshall and Martin 1980, Franke 1983). Plot size may also make it difficult to differentiate between colony relocation and colony mortality. In the most extreme cases, plots as small as 1000 ft^2, presumably 10' × 100' (approximately 3 m × 30.5 m), were used to evaluate individual mound treatments (Harris 1990a, 1990b). In such small plots, colonies moving out of the plot due to insecticidal pressure, or colonies immigrating to the plot from the untreated area immediately adjacent to the treatment plot may skew the results. Our study attempted to alleviate these problems by treating and evaluating all the mounds within a circular 0.1-ha assessment area, and also providing a buffer zone by treating all the mounds within 14 m of the edge of the circular assessment plot. Consequently, we feel the results obtained in this study are more robust than other studies employing less rigorous plot designs or smaller sized plots from which immigration of fire ant colonies can easily be confused with colony mortality.

Acknowledgments

We gratefully acknowledge the capable assistance provided by T. Lockley, A. Ladner, L. McAnally, and R. Cuevas for the many hours of field work involved in this study. D. F. Williams, D. F. Oi and J. H. Jarrett read earlier drafts of the manuscript and offered numerous comments.

References Cited

Callcott, A. M. and H. L. Collins. 1992. Temporal changes in a red imported fire ant (Hymenoptera: Formicidae) colony classification system following an insecticidal treatment. J. Entomol. Sci. 27: 345-353.

Collins, H. L., A.-M. Callcott, T. Lockley, A. Ladner and L. McAnally. 1992. Evaluation of boll weevil bait sticks for RIFA control. 1991 Annual Report, Imported Fire Ant Station, USDA, APHIS, PPQ, 189 pp mimeo.

Eden, W. G. and F. S. Arant. 1949. Control of the imported fire ant in Alabama. J. Econ. Entomol. 42: 976-979.

Franke, O. F. 1983. Efficacy of tests of single mound treatments for control of red imported fire ants. Southwest. Entomol. 8: 42-45.

Gardner, W. A. 1980. Imported fire ant control by mound drenches, 1979. Insect. Acaric. Tests 5: 209-210.

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.

Harris, J. P. 1990a. Red imported fire ant control on non-cropland in south Mississippi, 1989. Insect. Acaric. Tests 15: 315.

1990b. Red imported fire ant control on non-cropland in south Mississippi, 1988. Insect Acaric. Tests 15: 340.

Hays, S. B., P. M. Horton, J. A. Bass and D. Stanley. 1982. Colony movement of imported fire ants. J. Georgia Entomol. Soc. 17: 266-272.

Lofgren, C. S. and D. F. Williams. 1982. Avermectin B_1a, a highly potent inhibitor of reproduction by queens of the red imported fire ant. J. Econ. Entomol. 75: 798-803.

Markin, G. P., J. H. Dillier and H. L. Collins. 1973. Growth and development of colonies of the red imported fire ant, *Solenopsis invicta*. Ann. Entomol. Soc. Am. 66: 803-808.

Marshall, F. A. and P. B. Martin. 1980. Bermudagrass, attempts at fire ant suppression, Tifton, 1978. Insect. Acaric. Tests 5: 190.

Mirenda, J. T. and S. B. Vinson. 1981. Division of labor and specification of castes in the red imported fire ant *Solenopsis invicta* Buren. Anim. Behav. 29: 410-420.

SPSS Inc. 1992. SPSS/PC+™ Base System User's Guide: Version 6. Chicago, IL.

Vinson, S. B. and A. A. Sorensen. 1986. Imported fire ants: life history and impact. Texas Dept. Agric. 28 pp.

Williams, D. F. and C. S. Lofgren. 1983. Imported fire ant control: evaluation of several chemicals for individual mound treatments. J. Econ. Entomol. 76: 1201-1205.