Red Imported Fire Ants (Hymenoptera: Formicidae): Population Dynamics Following Treatment with Insecticidal Baits[1]

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ABSTRACT Evaluation of *Solenopsis invicta* Buren populations following insecticidal bait treatments is usually made on the basis of presence or absence of active nests. An alternative method is described in which population densities are based on total worker ants per hectare. Using these two methods, we found that there was essentially no difference in population levels of treated and untreated plots 27 to 36 months after application of two baits. In a more detailed study in which imported fire ant colonies were monitored for 156 weeks, the number of ant colonies had increased 327% after 44 weeks; however, the total number of ants in these same colonies was still 84% below pretreatment numbers. These data reflect the great difference in size of mature pretreatment colonies and small incipient posttreatment colonies. Based on the total ant population method, total ant numbers remained below that in the check area for 2 years. Thus, effective control of the pest extended well beyond that indicated by the nest count method.

INSECTICIDAL baits have been used for control of red (RIFA) and black imported fire ants (*Solenopsis invicta* Buren and *S. richteri* Forel) since the discovery of mirex (Lofgren et al. 1963, 1964). Baits containing this toxicant had several advantages, including the requirement for very small amounts of chemical; the highly efficient foraging behavior of the ants on the baits aided in their self-destruction. However, mirex baits also had some disadvantages. For example, mirex was highly persistent and even low application rates resulted in residues in nontarget organisms. Because the food attractant in the bait (soybean oil) was not species-specific, populations of some other ant species were also affected. The highly persistent nature of mirex and associated residue problems caused the withdrawal of mirex for RIFA control.

The lack of species-specificity with the soybean oil bait has been cited as a major cause of spread and increase of populations of RIFA (Buren et al. 1978, Buren 1980). This speculation, though undocumented, raised the possibility that application of toxic baits for RIFA control could lead to ever-increasing RIFA populations. The fact that areas treated with toxic baits may become reinfested with large numbers of incipient colonies has been reported (Lofgren and Weidhaas 1972, Summerlin et al. 1976, Apperson and Powell 1983). In all of these reports, however, the posttreatment reinfestation populations were monitored for 1 year or less.

[1] This article reports the results of research only. Mention of a proprietary product does not constitute endorsement or a recommendation for its use by USDA.

To assess long-range reinfestation patterns, we reviewed data from our bait tests done over the past 3 years. We resurveyed test plots on which significant control had been obtained with experimental bait toxicants. We also monitored the reinfestation of a large area near Albany, Ga. that was treated with bait by air. Two parameters of ant density per unit area were used: active nests (mounds) and total numbers of worker ants.

Materials and Methods

Populations of ants can be estimated either from numbers of individual nests or total numbers of individual ants. Since the basic functional unit of a eusocial insect is the colony (nest), population estimates are usually based on a tabulation of total colony numbers per unit area, despite the fact that the total number of individual ants in each colony may vary greatly. The colony unit may be of primary importance for many basic ecological studies of RIFA population dynamics, as well as changes in populations as a result of control techniques. However, the size of the colony nest and the number of ants per nest are of major importance from the standpoint of economic impact on crop production and public health. For example, damage to farm equipment when large RIFA nest mounds are impacted, reduction in crop yields from feeding by worker ants, and annoyance or medical hazards to man (Lofgren and Adams 1982) are all directly related to colony density and mound size. In other words, a colony of RIFA with <10,000 workers does not have the same relative importance as a mature colony with >100,000 workers. Thus, in almost all cases, estimation of the pest

Table 1. Method of determining total RIFA worker populations in field plots[a]

Category	Age of colony (mo)	Estimated no. of ants per colony (nest)	Avg no. of ants per colony weighting factor
1	1–2	<100	100
2	3–5	100–1,000	550
3	6–12	1,000–10,000	5,500
4	13–24	10,000–50,000	30,000
5	24–36	50,000–150,000	100,000

[a] Total population (0.4 ha) equals the sum of products obtained by multiplying total colonies (nests) in each category by corresponding weighting factor.

status of RIFA must be based on a method that relates potential damage or annoyance to the numbers of worker ants per unit area.

A review of the literature shows that almost all population estimates of RIFA following bait treatments have been based on nest counts. Recently, however, a new system was devised to aid in the evaluation of chemicals that caused effects other than direct killing action (Harlan et al. 1981, Lofgren and Williams 1982). The system requires two determinations: 1) an estimation of the total number of worker ants and 2) whether or not worker brood is present or absent. These observations were used to calculate population indices on which total impact of the chemical bait could be determined. While the two types of observations are subject to error that depends upon ability of the evaluators to estimate numbers of ants and various environmental factors such as drought or heavy rainfall, we have found that the results from replicated tests were consistent (unpublished data).

We used a variation of the previous method to compare RIFA populations on test plots before and 1 to 3 years after the application of toxic baits. Since we were interested only in population density, we did not categorize the colonies observed as normal or abnormal. Instead, we ranked the RIFA colonies into five categories as shown in Table 1. Then, using the colony population estimates of Markin et al. (1973) for colonies of different ages, we assigned an absolute population (weighting factor) to each category ranging from 100 for small or young colonies, to 100,000 for mature colonies (2 to 3 years old). After the ant colonies on each plot were ranked, the total number of ants per plot was determined by summing the products obtained from the total number of nests in each category and the appropriate weighting factor. A total of five treatment blocks in five different locations was evaluated. We used only those plots on which the reduction in active nests was >60%; however, control in the majority of the plots was >80%. The toxicants used in the ant baits were either Amdro (tetrahydro-5,5-dimethyl-2(*1H*)-pyrimidinone,[3-[4-(trifluoromethyl)phenyl]-1-[2-[4-(trifluoromethyl)phenyl]ethenyl]-2-propenylidene] hydrazone) or Eli Lilly EL-468 (*N*-[2-amino-3-nitro-5-(trifluoromethyl)propanamidephenyl]-2,2,3,3-tetrafluoroproponmide).

Descriptions of the tests conducted at Homerville, Ga., and Baldwin, Fla., were reported by Williams and Lofgren (1982); the Jasper, Fla. and Albany, Ga. tests were described by Williams and Lofgren (1981) and (1983), respectively. Results of the test conducted in the fifth area (Earlton, Fla.) were not published. In all cases, the baits consisted of the toxicant dissolved in soybean oil and impregnated on pregel defatted or degermed corn grits. The baits were broadcast uniformly over the test sites with ground or aerial dispersal equipment.

The procedure for estimations of total worker ants per nest (colony) involved a series of steps. The size of the nest was noted first; the nest was tapped and a small portion of the tumulus turned over. If worker ants from a large mound (50,000+ workers) boiled out and copious amounts of brood were noted, the colony was evaluated as category 5. On the other hand, very small nests (category 1) were easy to categorize since actual ant numbers <100 could be counted. Colonies in categories 2 through 4 required more time to evaluate; however, the broad range of ant numbers within each

Table 2. A comparison of RIFA populations pretreatment and 27 to 36 months posttreatment with toxic baits applied to roadsides[a]

Treatment	No. of plots	Avg no. of nests per 0.4 ha		% Change	Avg no. of ants per 0.4 ha		% Change
		Pretreatment	After 27–36 mo		Pretreatment	After 27–36 mo	
Homerville, Ga. (SR 122)							
Amdro	4	54	65	+20	2,277,500	3,547,700	+56
Check	4	41	52	+27	1,616,000	3,151,400	+95
Baldwin, Fla. (Interstate 10)							
Amdro	4	85	109	+28	3,989,500	8,760,400	+120
Check	4	116	122	+5	6,367,500	10,334,900	+62

[a] Maximum reduction in active nests following all treatments ranged from 60–100%. Bait was applied by helicopter. Application rates were 6 to 9 g (AI)/0.4 ha at Baldwin, Fla. and 5 to 8 g (AI)/0.4 ha at Homerville, Ga. No significant differences in reinfestation rates were detected ($P \leq 0.05$; analysis of variance).

Table 3. A comparison of RIFA populations pretreatment and 27 to 36 months posttreatment with toxic baits applied to pastures[a]

Treatment	No. of plots	Avg no. of nests per 0.4 ha		% Change	Avg no. of ants per 0.4 ha		% Change
		Pretreatment	After 27–36 mo		Pretreatment	After 27–36 mo	
Jasper, Fla.							
Amdro	3	65	32	−51	4,565,000	2,362,800	−48
EL-468	6	60	37	−38	3,798,500	2,705,400	−29
Check	3	64	43	−33	4,472,000	3,331,000	−26
Earlton, Fla.							
Amdro	5	48	26	−46	2,452,700	2,012,500	−18
Check	1	54	26	−52	1,911,200	1,932,200	+1

[a] Maximum reduction in active nests following all treatments ranged from 60–100%. Bait was applied with ground equipment. The application rate of Amdro was 4.3 g (AI)/0.4 ha; EL-468 was applied at rates of 8 to 16 g (AI)/0.4 ha. No significant differences in reinfestation rates were noted ($P \leq 0.05$; analysis of variance).

category made estimations easier. Environmental factors often made the evaluations difficult since the ants do not maintain their nest in hot, dry weather. Since the main portion of the colony might be 30 to 60 cm under the soil surface, this condition required careful observations to locate the nests followed by extensive excavation of the nest. RIFA population density estimates done by active nest counts were made in a similar manner. Any nest was considered active if at least 20 worker ants were found.

In all the test sites except Albany, Ga., pretreatment counts were compared to counts made after 27 to 36 months. At the Albany site we obtained data on the RIFA populations before treatment and 6, 19, 44, 116, and 156 weeks after treatment. This site (26.3 ha) was treated with Amdro at the rate of 9.88 g (AI)/ha with a fixed-wing aircraft. RIFA populations were determined on 10 subplots (0.2 ha) in the large treated and untreated plots. Data were subjected to an analysis of variance using cubic or quadratic linear models in the Statistical Analysis System (SAS) (Helwig and Council 1979). Nest density or total numbers of ants were the dependent variables.

Results

The data show that, along roadsides (Table 2), plots treated with Amdro, as well as check plots, were more heavily infested 27 to 36 months after treatment than they were before treatment by both evaluation methods. No significant differences in reinfestation rates attributable to the bait treatment were noted ($P \leq 0.05$).

Ant populations in both treated and untreated pasture plots (Table 3) decreased 27 to 36 months after Amdro or EL-468 was applied to the treated plots. Again, no significant differences in reinfestation rates attributable to the baits were detected ($P \leq 0.05$).

RIFA nest density in the Albany test site 6 weeks after Amdro treatment decreased to 0, while the nest density in the check increased slightly (Table 4, Fig. 1). Between 19 and 44 weeks after treatment, the subplots became heavily reinfested with small, young colonies (86% were in categories 1 and 2). The numbers of these colonies decreased to 24.4 after 116 weeks but increased to 31.7 at 156 weeks after treatment. The increase probably reflected our difficulty in locating small colonies in

Table 4. Categorization of RIFA colonies on plots located near Albany, Ga.

Time of colony count (wk)	Avg no. of ant colonies per 0.2 ha in following size categories					
	1	2	3	4	5	Total
Check plots						
0 (pretreatment)	0	0.6	0.8	1.7	8.1	11.2
6	0	0.6	0.9	2.7	10.1	14.2
19	0.2	0.9	0.5	1.5	8.1	11.2
44	0	0.5	0.9	0.8	11.1	13.3
116[a]	0.1	0.3	1.1	3.1	11.5	16.1
156[a]	0	2.0	1.4	3.1	13.1	20.0
Amdro plots						
0 (pretreatment)	0	0	0.7	1.0	10.6	12.3
6	0	0	0	0	0	0
19	0.2	0.3	0.3	0	0.1	0.9
44	24.2	21.0	5.2	1.2	0.9	52.5
116[b]	0	0.3	2.7	9.2	12.2	24.4
156[b]	0.8	2.2	5.2	7.8	15.7	31.7

[a] Average of 8 plots; all others 10 plots.
[b] Average of 6 plots; all others 10 plots.

Table 5. Changes in total ant population at Albany, Ga. test site

Test site	Pretreatment population/ha	% Change after following weeks				
		6	19	44	116	156
Check	865,800	+26	−1	+32	+44	+64
Amdro	1,092,800	−100	−99	−84	+37	+67

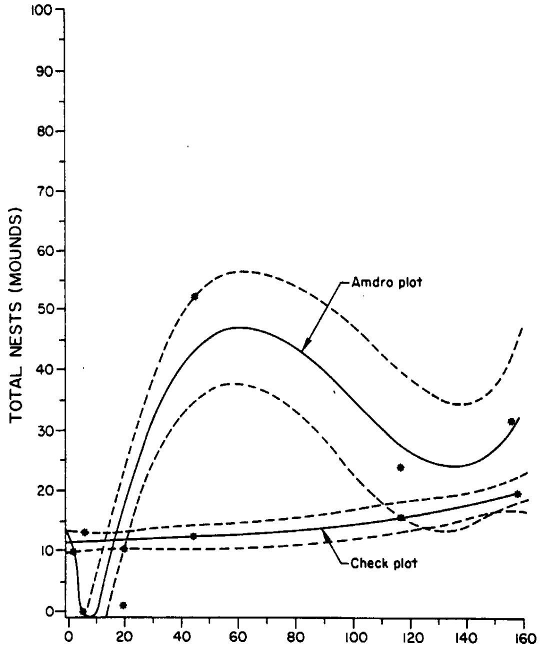

Fig. 1. Cubic regression analysis of total mounds in plots after treatment with Amdro (Albany, Ga.; solid lines are predicted mean values and slashed lines 95% confidence limits; asterisks indicate means of data points).

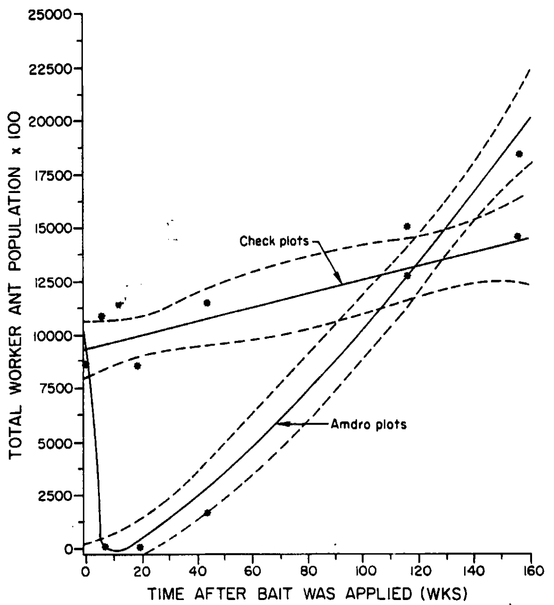

Fig. 2. Quadratic regression analysis of total [redacted] worker ants in plots after treatment with Amdro (Albany, Ga.; solid lines are predicted mean values and slashed lines 95% confidence limits; asterisks indicate means of data points).

the heavy vegetation and grass litter after 80 weeks. After 156 weeks, nests in the check subplots increased to 0.2 ha. These numbers represent a 79% increase in the check plots and a 158% increase in the Amdro plots.

When the same data were considered on the basis of total worker ant population (Fig. 2), a different picture of the impact of the bait treatment was revealed. The population of total ants dropped dramatically as the pretreatment nests were eliminated. However, after 40 to 60 weeks, when the nest counts rose dramatically, the total ant population was still very low. The reason for this pattern was obvious: the reinfestation nests were small (categories 1, 2, and 3 in Table 4) and each nest thus contained only a small fraction of the total ants in a mature colony nest. Fig. 2 indicates that the total ant population did not return to the levels in the check plot until more than 100 weeks after the baits were applied. Although the computer-generated curves (Fig. 2) suggest a significantly greater worker ant population after 160 weeks on the treated plots compared to the check plots, the actual populations in these plots (Table 5) increased about the same percentage (64 and 67%) when compared to the pretreatment levels.

Discussion

Reinfestation patterns following bait applications can vary as a result of habitat type and other environmental factors. For example, Lofgren and Weidhaas (1972) observed changes in RIFA nests before and 1 year after an application of mirex bait; they reported that the number of incipient colonies increased 10.5-fold over the pretreatment number of mature colonies on cultivated land. In pine woods, however, the situation was reversed and there was only 1 incipient colony for every 10 mature pretreatment nests. Four other habitat types averaged about one to one; overall, there was a 2-fold increase after 1 year. Similarly, Banks et al. (1973) presented reinfestation data following eradication trials that showed that incipient colonies along roadsides within 1 mile (1.6 km) of the treatment border of the eradication block ranged from 0 to 319 per ha. The reasons for variations in reinfestation rates appear obvious since success of RIFA queens in establishing new colonies is, at best, an extremely hazardous function because of their susceptibility to predation (Whitcomb et al. 1973) and various other biotic and abiotic factors.

The references cited and the new data presented in this paper clearly show that RIFA reinfestation rates can vary dramatically and that generalizations about the degree or extent of RIFA reinfestations following any particular treatment should not be made. This conclusion applies to areas within the same field as well as widely separated sites. However, when heavy reinfestations do occur, such as at the Albany site, these young colonies represent only a small fraction of the total worker ant population before treatment. During the ensuing years many of the young colonies die, but the number of ants in each surviving colony increases. After 3 years, the population is usually stabilized at the carrying capacity at that time. This level may be different than the original pretreatment population since other changes, such as food supply, may have altered the carrying capacity. This assumption is supported by the data from the Albany plots that showed a 79% increase in nest density and a 67% increase in total ants on the check plots, even though the land remained unused by man during the 3-year period of our observations.

Finally, we conclude that evaluations of RIFA populations should consider total ants as well as individual nests because the former may vary from <100 to >200,000 ants per nest. Consequently, assessment of control strategies based on numbers of nests can lead to the conclusion that a strategy has failed when, in fact, the number of actual ants is only a fraction of that occurring before the application of control. As stated earlier, the effectiveness of a control technique is related to the impact it has in reducing economic or public health hazards posed by the ants; these hazards are directly related to the probability of interaction between people or crops and the ants. Obviously, then, primary emphasis must be placed on total ants when assessing control techniques. Accordingly, we conclude that good control of RIFA at the Albany site lasted for about 1 to 1½ years and that the total ant numbers remained below those in the check area for 2 years.

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