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31
Chemical Baits: Specificity and Effects on Other Ant Species

D. F. Williams

Chemical baits have been used for many years to control pest ant species such as fire ants and leaf-cutting ants (see Cherrett, Chapter 29; Lofgren, Chapter 30). Prior to 1978, the most effective toxic baits contained the toxicant mirex which was developed in the early 1960s for control of the red and black imported fire ants (IFA), Solenopsis invicta and S. richteri (Lofgren et al. 1964). Because of its effectiveness (usually >95%), it replaced residual applications of heptachlor in 1962 as the preferred agent for IFA control. This chemical was also effective against leaf-cutting ants and is still used in some countries to control this pest. However, because several studies in the early 1970s revealed mirex residues in fish and wildlife (Lowe et al. 1971; Baetcke et al. 1972; Borthwick et al. 1973), the U.S. Environmental Protection Agency (EPA) in April 1973 filed notice in the Federal Register for a public hearing to determine if registrations of mirex should be cancelled. After several years of hearings, these registrations were withdrawn on December 31, 1977.

As reported by Lofgren (Chapter 30), the loss of mirex necessitated a concerted effort to discover and develop other chemical agents for IFA control, particularly ones that were environmentally acceptable. Two chemicals developed through this research were registered by the EPA, AC 217300 (tetrahydro-5,5-dimethyl-2(1H)-pyrimidinone [3-[4-(trifluoromethyl)phenyl]-1-[2-[4-(trifluoromethyl)phenyl] ethynyl]-2-propenylidene] hydrazone), the active component in Amdro® and Stauffer MV-678 (1-(8-methoxy-4,8-dimethylnonyl)-4-(methylethyl)benzene), the active ingredient in Pro-Drone®. Two additional chemicals currently being considered for registration are avermectin B_1, which causes irreversible sterility of the queen, and fenoxycarb (ISO proposed), which acts as an insect growth regulator (see Lofgren, Chapter 30).

Although the effects that the five bait toxicants just described exert on an IFA colony may differ, all of the chemicals use the same basic bait formulation, that is, the chemical is dissolved in a food attractant (usually soybean oil) and applied to a corn grit carrier. A major problem with this system is that large numbers of nontarget insects, especially beneficial ant species, feed on the bait and are affected by the toxicants. For example, Mr. H. T. Vanderford, an entomologist working for the Georgia Department of Agriculture, made numerous unpublished observations on nontarget ant species following applications of mirex bait from 1962 to 1967 in Georgia. He found high mortality (>75%) of 17 of the 37 species observed, moderate reductions of 13 others, and no effect on 7 species. In addition to these 37 species, more than a dozen other species were observed feeding on the bait; but he was unable to monitor the effects, if any. Clearly, these observations indicate that a very large number of other ant species are attracted to and feed on granular soybean oil baits. Markin et al. (1974) studied the effects of mirex bait on 14 common ant species in Louisiana and found that those species most affected were classified as oil-feeding with the exception of a Pheidole spp. which, although oil-loving, was not affected by the treatment. Following aerial applications of mirex bait in Texas, Summerlin et al. (1977) monitored 14 species of ants and found that omnivorous and highly predacious ants were the first to be affected by the bait and were eliminated within two weeks. After eight weeks, only two species of ants could be found in the study plot and both contained residues of mirex. Thus, mirex, a broad spectrum insecticide, was toxic to most of the ants that ingested it (Markin et al. 1972).

Although Amdro does not present the residue problem of mirex, it nevertheless still affects many nontarget ant species. Edmunson (1981) indicated in both laboratory and field studies that Amdro was relatively non-selective in its effects against several other ant species and that overall ant activity in the field was reduced 80 to 100% following treatments. A redeeming feature, however, was that all of the species affected, except one, recovered to pretreatment population levels within one year following treatment. On the other hand, Apperson et al. (1984) did not observe any deleterious effects from Amdro on the nontarget ant species he studied. The differences between the two studies might be explained by the fact that the study area used by Apperson et al. was heavily infested with S. invicta and this species generally outcompetes other ant species; thus, few other ant species were collected. Edmunson, on the other hand, wanted to observe the maximum effects of Amdro so he conducted a study in an area free of S. invicta, although some colonies were located nearby. Therefore, he not only had more species but greater numbers on which to evaluate the effects of Amdro. Stimac (personal communication) also indicated that Amdro exhibited deleterious effects on nontarget ant species in studies he conducted in a pasture near Gainesville, Florida.

Another problem with baits such as mirex and Amdro is the ability of the most aggressive and highly reproductive ant species to quickly reinfest areas following bait treatments. This is especially true if all competitors, even those offering a small degree of competition, are also eliminated by the bait treatment. Reinfestation of treated areas by S. invicta is well documented (Lofgren et al. 1964; Lofgren and Weidhaas 1972; Markin et al. 1974; Summerlin et al. 1976, 1977; Brown 1980; Apperson et al. 1984). Because S. invicta colonies produce large numbers of sexuals (3,000 to 5,000/year), newly-mated queens quickly inundate bait-treated areas. If these queens are free from competition from other ant species or conspecific colonies, then large numbers of incipient colonies can be established. In areas heavily infested with S. invicta, workers from the conspecific colonies are the most significant mortality factor for newly-mated queens (Whitcomb et al. 1973). In contrast, in lightly infested areas, Conomyrma insana (Buckley) is the significant mortality factor for newly-mated queens of S. invicta. Whitcomb et al. (1973) also indicated that 11 other species of ants were seen attacking these queens. Thus, it is obvious that predation by already established ant species plays a major role in determining the success of colony-founding queens.

Studies of the effects of Pro-Drone, fenoxycarb, and avermectin B_1 on nontarget insects, especially ants, have been or are currently underway; but at the present time, no published information is available. L. Lemke (personal communication) stated that in her studies in South Carolina Pro-Drone caused no deleterious effects on nontarget ants. However, no pretreatment counts were recorded, which may have influenced the interpretation of the results. S. A. Phillips (personal communication) indicated that Pro-Drone applied over a large area in Texas had no effect on nontarget ants and little effect on target ants. In contrast, S. B. Vinson (personal communication) found some detrimental effects on nontarget ant species following Pro-Drone applications to IFA populations in Texas. Studies presently underway by D. F. Williams et al. (unpublished data) indicate that both fenoxycarb and avermectin B_1 reduce nontarget ant populations; however, all affected species are returning to pretreatment population levels after one year.

Although insect growth regulators and other chemicals with different modes of action may have lesser effects on nontarget arthropods or affect fewer species than the stomach poisons and neurotoxins, they probably will still have deleterious effects on many nontarget organisms. This potential problem is particularly true if they are attracted to and feed on the soybean oil in the bait. Unfortunately, little hope exists at this time of finding a replacement for soybean oil because (1) it is an excellent attractant for IFA, (2) it is reasonably priced and readily available, (3) most chemical control agents easily dissolve in it, and (4) it is readily absorbed on carriers, making an excellent flowable bait.

If the problem of non-selectivity is to be overcome, all potential areas of research should be explored. For example, size and texture of bait particles, timing of applications, and rates of application may offer some promise in making baits more specific to S. invicta. The ant species that are the most aggressive foragers tend to dominate baits soon after they are applied; therefore, larger particles may not be readily picked up by fast foraging nontarget ant species giving S. invicta a chance to displace them at the bait. Applying the baits at optimum foraging and feeding times for S. invicta would also lessen the chances of other ant species feeding on the bait. The rate of application may play a role in selectivity since aggressive foragers such as S. invicta would collect most, if not all, of the bait applied at optimal rates; but amounts above optimal would allow other ant species greater access to the bait.

The previously mentioned areas of research deal with the improvement of the fire ant bait in its present form; i.e., the soybean oil and toxicant applied to a granular carrier. Four other areas of bait toxicant research which do not include the soybean oil attractant offer promise. Examples of these are: (1) pheromones, (2) phagostimulants, (3) biological control agents, and (4) carriers and formulations. Research in each of these categories is underway, but much more needs to be done.

The use of pheromones to increase the specificity of baits to the target insect appears very promising. Elucidation of portions of the queen and trail pheromone complexes have been reported (Rocca et al. 1983a, 1983b; Vander Meer et al. 1981), and Vander Meer (1983) presented an indepth review of the pheromones found in S. invicta and the role they play in this species' behavior. Some research on baits in combination with trail pheromones to control leaf-cutting ants has been reported (see Kermarrec, Chapter 29). While some of the baits appeared more attractive, they did not surpass the attractiveness of food odors already in the bait. Other attractants that look very interesting include the colony odors involved in nestmate recognition. These may involve cuticular hydrocarbons which make up 65 to 75% of the ant's cuticular lipids (Lok et al. 1975). These fire ant species "recognition" chemicals, when combined with toxicants, may aid in developing species specific baits. Vander Meer (1983) indicated that the four species of Solenopsis, S. invicta, S. geminata, S. xyloni, and S. richteri, can all be identified by their cuticular hydrocarbon patterns. Also of special interest is the queen recognition pheromone which is discussed by Glancey in Chapter 19. Surrogate queens (rubber septa, wood sticks) treated with these compounds are readily carried to the nest. Thus, the pheromone may offer a means of enticing foragers to collect and carry bait particles back to their nestmates.

Phagostimulants, plant chemicals which elicit feeding responses, are another area of research that should be pursued. Most insects are attracted to specific food substances and fire ants and leaf-cutting ants are no exception. For example, fire ant workers are highly attracted to, and feed on, the calyx of okra flowers (Vander Meer, unpublished data). If the attractants or phagostimulants found in okra could be incorporated into baits, then the possibility of enhancing their attractiveness to fire ants would increase.

Biological agents can be very species specific in their effects on certain organisms. If a pathogen (bacteria, virus, or fungus) was discovered that exerted an effect on one or more stages of only the target insect, then introducing this infectious agent into an IFA population would be a species-specific control measure. Also, pathogens may be successfully utilized as stress agents rather than outright mortality factors. For example, if pathogens can be used to stress a colony, other species of ants may then be able to successfully compete for resources and displace the treated colony. Jouvenaz (Chapter 27) presents a review of the status of diseases of IFA. None of these diseases seem to offer a solution; however, others undoubtedly remain to be discovered. The signing of a cooperative agreement between USDA, ARS, Insects Affecting Man and Animals Research Laboratory, Gainesville, Florida, and EMBRAPA—the Empresa Brasileira de Pesquisa Agropecuaria of the Brazilian Ministry of Agriculture, has provided the basis for an extensive search for other fire ant diseases and parasites. If a suitable IFA pathogen could be mass-produced, baits inoculated with this organism could be formulated and applied to IFA populations, just as the current chemical baits are applied.

Carrier and formulation research also offers some promise in bait specificity. The bait carrier and formulation used against IFA is a pregel defatted corn grit containing 30% once-refined soybean oil in which the chemical toxicant is dissolved. The problem with this formulation, as previously mentioned, is the attractiveness of the soybean oil to other ants. Recent laboratory and field studies by Williams et al. (unpublished data) have shown good control of IFA with a bait composed only of fenoxycarb and the carrier, pregel defatted corn grits. The carrier was immersed in a 2.5% acetone solution of the technical chemical for 30 minutes, removed, and spread out in a shallow pan to air dry under a fume hood for 24 hours. The bait was then ready for use. Apparently, enough residual oil remained in the defatted corn grits to attract foraging workers of the fire ant. Also, technical fenoxycarb has a low repellency to the IFA workers. Studies are underway to determine if, in fact, this formulation with greatly reduced oil content lessens the effect of fenoxycarb on other ant species.

Food flow studies of Howard and Tschinkel (1981), Sorensen and Vinson (1981), and Sorensen et al. (1983) indicate that we may target baits towards queens and larvae, bypassing workers, by utilizing protein baits. Substituting a protein bait for the soybean oil may allow us to utilize otherwise unusable toxicants.

Another approach to IFA baits has been the use of a "natural" component of their diet, insect pupae. House fly (Musca domestica) and eye gnat (Hippelates pusio) pupae are not only very attractive to fire ants but also make a very flowable carrier which is easily dispersed with application equipment. The acetone-immersing method described previously can be used to apply the technical chemical to the pupae. The treated pupae then become an attractant-carrier with the toxicant trapped inside until the IFA feed on it. In previous studies, Williams et al. (unpublished data) have shown very good control with house fly pupae treated with fenoxycarb (Table 1). Control was as good as that achieved with the Amdro standard, and the amount of active ingredient applied was much smaller. In laboratory studies, some nontarget ant species were found not to feed on pupae, thus imparting some bait specificity.

In conclusion, the area of bait specificity is one in which little interest has been shown. Most control programs using insecticides, including bait techniques, have been developed with little regard to the impact these chemicals might have on the environment. The majority of available insecticides are broad spectrum because developmental costs are extremely high, and highly specific chemicals can quickly become very unprofitable, especially in the case of small markets (Zeck 1985). Nevertheless, if we are to develop programs for better management of insect populations, such as the IFAs and the leaf-cutting ants, we must minimize the impact of these programs on nontarget species. The future goal of pest management for fire ants and leaf-cutting ants should be to provide long-term population suppression. For us to accomplish this goal, we must utilize any method or combination of methods that reduce populations of the pest species while minimizing the effects on beneficial and other nontarget species. Thus, we are seeking management schemes which offer more bait selectivity, defined by Bartlett (1964) as the capacity of a treatment to spare natural enemies while destroying pests. To further illustrate this principle, Ripper et al. (1956) have divided selectivity into two types, ecological and physiological. Ecological selectivity is obtained by manipulating the amount of chemical toxicant reaching the target species with little or no effects on the nontarget species. Physiological selectivity would occur by making the chemical itself more selective by designing the molecular structure of the toxicant so that it is more toxic to the target species than it is to nontarget species (Zeck 1985). Both of these methods have great potential, especially in view of our rapidly increasing knowledge of ant ecology, physiology, and biochemistry.

TABLE 1. Control of IFA with fenoxycarb and AC 217300 (Amdro) on house fly pupae or pregel defatted corn grits. Alachua County, FL, April 1982. (Avg. of three 1-acre plots.)

Treatment	g AI/ acre	Pretreatment counts		% reduction in PI after wks indicated[d]		
		No. mounds[c]	PI[e]	6	14	18
AC 217300[a]	0.81	52	1203	20	53	62
Fenoxycarb[a]	0.66	49	1117	78	92	85
AC 217300 (std.)[b]	4.35	48	1065	69	92	89
Fenoxycarb (std.)[b]	3.50	45	1005	79	95	94
Untreated check	—	52	1132	28	33	32

[a]House fly pupae baits were prepared by dissolving the test chemical in acetone (2.5% AC 217300 and 3.0% fenoxycarb), immersing the pupae in this solution for 30 minutes, and air drying under a fume hood for 24 hours.
[b]Standard (std.) baits consisted of 70% pregel defatted corn grits impregnated with 30% of the soybean oil-toxicant solution.
[c]No. mounds per 1/2-acre circle within center of each 1-acre square plot.
[d]Corrected for check mortality by Abbott's formula.
[e]Population index (PI). See Banks, Chapter 32, for method of calculation.

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