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An Improved Mirex Bait Formulation for Control of Imported Fire Ants[1,2,3]

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ABSTRACT

A new method was developed for formulating mirex bait for control of *Solenopsis richteri* Forel and *Solenopsis invicta* Buren. The mirex is incorporated into the outer layer of soybean oil on the corncob grits and the bait is coated with an acrylic latex. The oil content of the formulation can be increased by one-third, thus more oil or food attractant is available to the ants. Incorporation of the mirex in the oil on the surface of the grits makes a greater percentage of the insecticide available to the ants (89 vs. 55% in the standard bait).

Field tests in Georgia with aerial applications of the new formulation against *S. invicta* showed that the coated bait containing 0.1% mirex and applied at 1.0 lb per acre gave control comparable to standard bait containing 0.3% mirex applied at a rate of 1¼ lb per acre (99.6 vs. 99.1%, respectively).

Mirex bait, the standard control agent used against the imported fire ants, *Solenopsis richteri* Forel and *Solenopsis invicta* Buren, since 1962, is composed of a food attractant (once-refined soybean oil) and a toxicant (mirex) and is impregnated on a carrier (corncob grits) for easy application. The formulation was developed at Gulfport, Miss., in 1960–61 and reported by Lofgren et al. (1962, 1963, 1964) and Stringer et al. (1964). Subsequently, as a result of research and development studies made concurrently with control programs, the rate of application was reduced and the concentration of toxicant in the bait was increased (from an initial 10 lb/acre of bait containing 0.075% mirex to the present 1.25 lb/acre of bait containing 0.3% mirex). However, the basic formulation has remained the same except that the toxicant was increased with a corresponding decrease in oil content (Banks et al., unpublished data).

Markin and Hill (1971) found that encapsulation of the soybean oil-mirex produced a bait that gave as good control as the standard bait and was superior in withstanding aging and weathering in the field. However, high costs of production and lack of available equipment for handling and applying this bait has prevented its use on a large scale. Meanwhile, in 1968, we had begun studies at the Insects Affecting Man and Animals Laboratory, Gainesville, Fla., in hopes of making a low-cost improvement of the corncob grit formulation. We found that performance of the bait could be improved by coating the

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[2] This paper reflects the results of research only. Mention of a commercial or proprietary product or a pesticide does not constitute endorsement or recommendation by the USDA. Received for publication 5 July 1972.
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completed formulation with acrylic latex (Banks et al. 1973). The oil content of the coated bait could be increased by as much as 33%. Moreover, the preliminary data from these studies showed that the ants could extract ca. 70% of the oil from the latex-coated formulations vs. ca. 60% from the standard (Lofgren et al. 1963). The extra oil that could be added to the formulation plus the increased amount the ants extracted combined to give an increase of 92–288% in the amount of oil available to the ants from the latex-coated bait under various environmental conditions.

In early field tests, the latex-coated bait gave kill of the ants comparable to that given by the standard and by the microencapsulated baits and in cool weather gave faster kill than did the other formulations (Banks et al. 1972).

The present paper reports the results of additional laboratory tests made to (1) verify that more oil is indeed available to the ants from the latex-coated baits, (2) report on a new formulation that incorporates the mirex in the oil on the surface of the corncob grits, and (3) presents data from large scale field trials in which the latex-coated and the standard mirex baits were compared as controls for imported fire ants.

Methods and Materials

Oil Availability Tests

Nontoxic baits (1 kg of each) used in the studies of oil availability were prepared in the laboratory with a kitchen food mixer and were composed of 80 or 85% corncob grits and 20 or 15% soybean oil. All formulations containing 20% oil and ½ the formulations containing 15% oil were coated with latex by spraying the completed formulations with a 40% aqueous solution of AA-421 acrylic latex (Morton Chemical Co.) at the rate of 100 ml/kg as they tumbled in a mixer. Then, 1-g samples of the baits were placed in small weighing dishes and offered to laboratory colonies containing ca. 5000 worker ants each (3 colonies for each formulation). As the ants removed the bait from the dishes, additional bait was provided and the spent grits discarded by the ants were collected. The remaining oil in the spent grits was then extracted with hexane in a Soxhlet apparatus, and the data obtained from the extractions were used to calculate the percentage of oil that the ants had removed. In addition, we collected spent grits from the refuse piles of ant colonies in the field after large-scale aerial applications of bait, returned these grits to the laboratory and extracted the remaining oil with hexane and calculated the percentage of oil removed by the ants. Also, the extracted oil was analyzed by gas-liquid chromatography to determine the amount of mirex remaining and the amount removed from the bait.

Field Tests

Field tests against natural infestations of the red imported fire ant, *S. invicta* were made with the standard mirex bait and 3 formulations of latex-coated mirex bait (prepared by Allied Chemical Corp.) as follows:

(1) The standard formulation, composed of 0.3% mirex, 14.7% soybean oil and 85% corncob grits, was prepared by dissolving the mirex in the soybean oil and then spraying the solution onto the grits as they tumbled in a mixer.

(2) A latex-coated formulation composed of 0.38% mirex, 18.62% soybean oil, 71% corncob grits and 10.0% of a 40% aqueous solution of AA-421 acrylic latex was prepared by spraying the soybean oil-mirex solution on the grits as indicated for the standard formulation and tumbling for 5 min. Then the latex solution was sprayed onto the bait, and the total formulation was tumbled an additional 5 min.

(3) A latex-coated formulation composed of 0.15% mirex, 18.85% soybean oil, 71% corncob grits, and 10% of a 40% aqueous solution of AA-421 acrylic latex was prepared as the latex-coated 0.38% mirex formulation.

(4) A latex-coated formulation composed of 0.1% mirex, 18.9% soybean oil 71% corncob grits, and 10% of a 40% aqueous solution of AA-421 acrylic latex was prepared by spraying the grits with 14.0% of the oil (which contained no mirex) as they tumbled in the mixer. The grits were then removed from the mixer, allowed to stand for 24 hr to absorb the oil, returned to the mixer and sprayed with the remaining 4.9% soybean oil (containing the 0.1% mirex). After mixing for ca. 5 min, the formulation was sprayed with the latex solution and allowed to tumble for an additional 5 min.

The field tests were made in 2 series. In the first, during the fall of 1970 near Fitzgerald, Ga., the latex-coated 0.38% mirex bait applied at a rate of 0.75 and 1.0 lb/acre (ca. 40,000 acres at each rate) and the standard 0.3% mirex bait applied at a rate of 1.25 lb/acre (ca. 120,000 acres) were used. In the 2nd series, during the spring of 1971 near Tifton, Ga., the latex-coated 0.15% (ca. 30,000 acres) and 0.1% (ca. 36,500 acres) mirex baits were applied at a rate of 1.0 lb/acre and the 0.3% standard (ca. 150,000 acres) was applied at a rate of 1.25 lb/acre.

The applications of baits were made by multi-engine commercial applicator aircraft under the supervision of personnel of the Plant Protection Division (now a part of APHIS, USDA). All aircraft were guided during application by electronic signal and were equipped with auger-fed dispersal systems mounted within the wings of the aircraft. All applications were dispersed from an altitude of 700 ft.

Evaluation plots ranging in size from ¼ to 2 acres were selected in each area before treatment. Counts were made of active mounds on each plot before treatment and at 8 and 30 weeks posttreatment in Series 1 and at 4, 8, and 13 weeks posttreatment in Series 2. During each count the ant mounds on each plot were opened with a spade and

Table 1.—Percentage decrease in oil and mirex in standard and latex-coated baits after exposure to imported fire ants.

Formulation[a]	Oil content (%)		% of original	
	Original	After exposure	Oil lost	Mirex lost
	Laboratory colonies[b]			
Standard	15.5	10.6	31.6	
Latex coated	16.0	9.3	41.9	
	20.6	10.7	48.1	
	Field colonies[c]			
Standard	15.1	6.5	56.7	54.9
Latex-coated 0.15%	19.3	5.3	72.5	70.6
Latex-coated 0.1%	19.1	5.5	71.4	88.7

[a] Formulations for laboratory colonies composed of corncob grits and soybean oil without toxicant. Formulations for field colonies composed of corncob grits, 85% for standard and 71% for coated baits; of soybean oil—14.7% for standard, 18.85% and 18.9% for coated formulations; and mirex—0.3% for standard, 0.15% and 0.1% for coated formulations. All latex-coated formulations sprayed after formulation with 40% aqueous solution of acrylic latex.
[b] Avg for 3 colonies.
[c] Avg for 10 colonies.

examined for the presence of live worker ants; a mound was considered active if 20 or more live workers were present.

Results

Oil Availability

The laboratory tests showed that the ants removed considerably more oil from the latex-coated formulations than from the standard bait (Table 1). The ants removed ca. 33% more oil from the latex-coated bait containing 15% oil and ca. 52% more from the bait with 20% oil than from the standard.

Also, the samples of grits collected in the field showed that from 26 to 27% more oil was removed from the latex-coated formulations than from the standard. Of course, we do not know whether all the oil was taken by the ants or a portion lost to the soil on which the bait fell; however, the data indicate that the coated formulations had more removable oil; also, gas-liquid chromatography of the oil extracted from the grits showed that an average of 70.6 and 88.7% of the mirex had been removed from the coated formulations containing 0.15 and 0.1% mirex, respectively, compared with only 54.9% from the standard formulation. Thus, application of the mirex in the outer coating of oil only significantly increased the availability of the toxicant to the ants.

Field Tests

In both series of field tests the latex-coated mirex baits gave control comparable to that obtained with the standard (Table 2). In Series 1, faster kill was obtained with the coated 0.38% mirex bait at both rates of application than with the standard, and after 8 weeks, the latex-coated bait had reduced the number of active mounds 91 and 95% when applied at rates of 1.0 and 0.75 lb/acre, respectively; the standard had given 82% reduction. However, by 30 weeks postreatment, kill was about equal with 98, 100, and 97%, respectively.

In Series 2, the 0.15 and 0.1% mirex baits were comparable in effectiveness to the standard 0.3% mirex bait. Maximum kill (at 8 weeks posttreatment) showed less than 1% difference with the 3 formulations. By 13 weeks posttreatment, small new colonies were apparent on many plots as a result of mating flights that had occurred at or near the time of application.

Discussion

Our tests of the availability of oil from the latex-coated and standard formulations again showed that more oil was available from the coated formulations. Examination of the coated bait under a microscope revealed that a portion of the oil seemed to be trapped on or near the surface of the grit and retained in the latex as it dried. Since the ants are apparently unable to extract oil that penetrates the inner pores of the grit, the entrapment of the oil on or near the surface by the latex makes more of

Table 2.—Control of natural infestations of imported fire ants with aerial application of standard and latex-coated mirex baits in Georgia in 1970–71.

Bait formulation	% mirex	Rate of application/acre		Total no. of active fire ant mounds pretreatment	% reduction in number of active mounds after indicated weeks			
		Bait (lb)	Toxicant (g)		4[a]	8	13[b]	30
				Series 1				
Standard	0.3	1.25	1.70	1101		82.9		97.3
Latex-coated	.38	0.75	1.29	782		95.4		100[c]
		1.0	1.72	1225		91.6		98.3
				Series 2				
Standard	.3	1.25	1.70	1123	95.4	99.1	98.5	
Latex-coated	.15	1.00	0.681	985	98.2	99.8	90.6	
Latex-coated	.1	1.0	.454	909	93.7	99.6	96.4	

[a] Reductions at 4 weeks calculated from 1098 mounds for standard bait, and 811 mounds from latex-coated 0.1% bait.
[b] Decrease in percentage reductions for all treatments in Series 2 at 13 weeks due to new colonies arising from reinfestation by queens from nuptial flights at or near time of treatment.
[c] Reduction at 30 weeks calculated from 713 mounds.

it available to the ants. The latex coating thus allows better utilization of the oil and toxicant by making a greater portion available to the ants.

The improved efficacy of the latex-coated baits demonstrated in our earlier studies (Banks et al. 1972) was further substantiated by the Series 1 field tests. Performance of the bait was improved by the coating, but a portion of the mirex in the formulation was still unavailable to the ants and was being discarded with the grits. (The ants were removing a maximum of ca. 71%.) If essentially all the mirex could be made available to the ants, less mirex could be used in the formulation with no loss of effectiveness. Utilization of such a bait would place far less mirex on each acre and the discarded grits would contain less mirex to be picked up by nontarget organisms. Since the mirex in the bait is dissolved in the soybean oil making all the mirex available meant making all the oil available or concentrating the mirex in the oil that is available to the ants. We knew of no way to alter the corncob grits so the ants could extract all the oil and of no alternate carriers from which all the oil could be extracted. However, we tried several substances that might seal the inner portion of the grits so the oil containing the mirex could not penetrate and would remain on or near the surface—linseed oil, acidless tallow oil, gelatin, and soybean oil containing monoglycerides of lard or other thixotrophic agents. Formulations made with these materials were either too sticky to flow or were unacceptable to the ants. Since none of these materials was satisfactory, we decided to impregnate the grits with plain oil and allow enough time for the oil to penetrate into the grits, hoping that this course might delay diffusion of mirex from a 2nd coat of oil applied later. This was, in fact, the case: The use of mirex in the 2nd batch of oil increased the availability of the toxicant to the ants by ca. 18% compared with the other latex-coated formulation and by ca. 34% compared with the standard.

The difference in the availability of mirex with the coated 0.1% formulation and the standard bait is even more dramatic when the oil loss factor for severe environmental conditions is considered. Banks et al. (1973) reported that after exposure to hot sand for several hours, 37.6% of the original oil in the latex-coated formulation was available to the ants compared with only 17.7% in the standard formulation. Then, with the standard bait (0.3% mirex) applied at a rate of 1.25 lb/acre, 300 mg/acre of mirex would be available to the ants, and with the latex-coated 0.1% bait applied at a rate of 1.0 lb/acre, 150 mg/acre of mirex would be available. Therefore, we see that although almost 4× as much mirex was applied originally with the standard formulation as with the latex-coated formulation (1.7 g vs. 0.454 g/acre) the amount of mirex available to the ants differed by only a factor of 2×.

Since the lesser amount of mirex in the latex-coated 0.1% formulation gave control comparable to that given by the standard, a reduction of the mirex content in the standard might be feasible. However, it could not be nearly as great as with the latex-coated formulation: the amount of mirex available from the latex-coated 0.1% formulation applied at 1.0 lb/acre could only be equalled by applying a 0.1% standard formulation at a rate of 1.89 lb/acre.

Coating the mirex bait with the latex thus definitely improved its efficacy, and the latex-coated 0.1% formulation was superior to the other coated formulations because it afforded the greatest reduction in amount of toxicant applied per acre (73.5% at 1.0 lb/acre compared with the standard). Also, application of the oil in 2 steps produced a drier, more flowable bait than the other latex baits.

The reduced amount of mirex in the formulation and the 75% reduction in the amount of mirex applied per acre should theoretically reduce the overall residues in the environment. Recent data (Banks et al. unpublished) suggest, however, that the residue levels in some nontarget species may approach the magnitudes found following applications of the standard 0.3% bait. Thus increasing the availability of mirex to the ants probably also increases its availability to some other nontarget species. However, since the total amount of mirex per acre is 75% less, the mirex burden per acre is reduced proportionately and, hopefully, disappearance of mirex from the ecosystem will be more rapid.

Further reductions in the amount of mirex applied per acre may be possible with the latex-coated baits, and tests are in progress to evaluate this possibility.

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