REPRINTED FROM:

Applied Myrmecology

A World Perspective

EDITED BY

Robert K. Vander Meer,
Klaus Jaffe, and Aragua Cedeno

Westview Press
BOULDER, SAN FRANCISCO, & OXFORD

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Effects of Fenoxycarb Baits on Laboratory Colonies of the Pharaoh's Ant, *Monomorium pharaonis*

D.F. Williams

INTRODUCTION

The pharaoh's ant, *Monomorium pharaonis* (Linnaeus), probably originated in North Africa and the Middle East, but has spread via commerce to most cosmopolitan areas of the world (Wheeler 1910). In most regions, the Pharaoh's ant is a major indoor pest (Edwards 1986). However, it nests outdoors in tropical climates and persists in temperate regions where the temperature is artificially maintained, such as refuse dumps (Kohn and Vlcek 1984). In nontropical climates, infestations usually occur in heated buildings such as large office and apartment complexes, factories, food establishments and hospitals (Edwards 1985). Especially troublesome are the problems they cause in hospitals, where they contaminate equipment and sterile packaging, penetrate I.V. solutions and tubing and feed on dressed wounds (See Eichler, this volume). Worker ants are capable of carrying Salmonella, Streptococcus, Staphylococcus, Clostridium and Pseudomonas pathogens (Beatson 1972). Infestation rates in London hospitals reach 30%; and in Prague, Czechoslovakia 86% (Edwards 1985; Rupes et al. 1983, respectively). United States medical facilities in Texas and Florida have also experienced ongoing infestations (Wilson and Booth 1981; Williams, unpublished data).

A pharaoh's ant colony consists of several nests with free worker movement and no antagonism between nests (Edwards 1981). In the cooler regions, the ants usually nest indoors, especially in inaccessible areas such as wall spaces, plumbing and duct shafts and foundations. Nests are generally polygynous and mating occurs within the nest. New colonies arise from "budding" (sociotomy) of the main colony when several workers (with or without a queen) carry eggs, larvae and pupae to a new site (Edwards 1986). Workers can live about 9 to 10 weeks while queens may live 39 weeks (Peacock and Baxter 1950), or more than 52 weeks in the lab (Edwards 1986). The oviposition rate during most of the queen's life is 25 to 35 eggs per day (Edwards 1986).

The earliest reports on pharaoh's ant control methods were published 100 years ago by Bellevoye (1889) and Riley (1889). A few years later, Lintner (1895) reported on the use of pyrethrum against *M. pharaonis*; however, not until the 1950's were inorganic and organic insecticides widely used against this pest (Rogers and Herrick 1953, Morgan and Price 1954,

Papworth 1958). Edwards (1986) gives an excellent review of control methods.

Conventional control techniques utilizing sprays and dusts are usually ineffective against pharaoh's ant. As in other social insect pests (See Banks, this section), contact insecticides primarily affect a small percentage of foraging workers. Also, the foraging habits of workers make it possible for them to largely avoid contact with the insecticide. The polygynous and polynest nature of the ant makes it more difficult to obtain total insecticide coverage. Even without foraging workers, colonies can survive for long periods on previously-stored food (Kretzschmar and Brendt 1976). Another reason new queens are less vulnerable to these control methods is that mating occurs inside the nests. Finally, because *M. pharaonis* prefer to nest in interior walls and spaces, they can infiltrate an entire building even if an insecticide covers the outer surface. Therefore, toxic baits are preferable, either alone or in combination with residual insecticide applications. Some commercially available pharaoh's ant baits are Pharorid (methoprene, Zoecon Corporation, Dallas, TX, 75234, USA), Drax (boric acid, R Value, Inc., Smyrna GA, 30081, USA), and Maxforce Pharaoh Ant Killer (hydramethylnon, American Cyanamid Company, Wayne, NJ, 07470, USA). Complete control is sometimes achieved; however, too often the control fails. Additional safe, effective chemicals and attractive bait formulations are still necessary. The basic biology and ecology of this insect must be researched for developing new control strategies. Intensive care, burn and neonatal units in hospitals, school lunchrooms, restaurants, homes and apartment complexes all come under attack by pharaoh's ants, making control vitally important.

The insect growth regulator, fenoxycarb (Maag Agrochemicals, Inc., Vero Beach, Florida 32961-6430) is presently registered as a toxic-bait (Logic) and has shown excellent control against the imported fire ant, *Solenopsis invicta* Buren (Banks et al. 1988). This paper reports our efforts to develop and evaluate fenoxycarb bait formulations against the pharaoh's ant in the laboratory and under natural conditions.

MATERIALS AND METHODS

Colony Rearing

The laboratory colonies were maintained in nesters which were plastic sweater boxes 35.6 cm long X 26.7 cm wide X 17.1 cm deep (Tucker Housewares, Arlington, TX 76011) coated with Teflon 30B (E. I. DuPont De Nemours & Co., INC., Polymer Products Department, Wilmington, Del 19898) on the inside walls (10 cm band). One or more rearing cells (depending on colony size) - a plastic petri dish (100 mm X 100 mm square X 15 mm deep) with a base of flesh-tone colored dental plaster (Dentsply/York Division, 570 West College Avenue, York, Pa 17405 USA) - were covered with red acetate and placed inside each nester. The rearing cells contained numerous queens, brood (eggs, larvae, and pupae) and workers. The colonies received the standard diet of insects (adult house flies and mosquitoes), hardboiled chicken egg yolk, and honey-agar twice weekly. They were maintained at 30 ± 2°C and 75 ± 10% RH, with a 12 hr daylight cycle. A polystyrene weighboat (100ml cap., Curtin Matheson Scientific, Inc., P.O. Box 1546, Houston, TX 77251) containing water-saturated cotton provided moisture. Water was added as needed to the cotton.

TABLE 1. Acceptability of fats and oils to Pharaoh's ants, *Monomorium pharaonis*.

Fat or oil	No. colonies	Acceptance ratio[a]
lard	12	1.388 ± 0.548a
Arrowhead Mills peanut butter oil	65	1.000 ± 0.000b
Smucker's peanut butter oil	6	0.893 ± 0.080b
Arrowhead Mills peanut butter	12	0.887 ± 0.504b
Butter	12	0.870 ± 0.156bc
Olive oil	35	0.801 ± 0.607bc
Tree of Life peanut butter oil	6	0.791 ± 0.121bc
Knudsen Family peanut butter oil	6	0.783 ± 0.159bc
Pumpkinseed oil	35	0.748 ± 0.264bc
Crisco	12	0.698 ± 0.174bc
Publix peanut butter oil	6	0.565 ± 0.125cd
Tuna oil[b]	29	0.397 ± 0.242de
Avocado oil	29	0.362 ± 0.225def
Soybean oil	6	0.353 ± 0.051def
Coconut oil	6	0.353 ± 0.083def
Almond oil	6	0.298 ± 0.255defg
Once refined soybean oil	29	0.253 ± 0.162efg
Corn oil	6	0.223 ± 0.181efg
Sunflower oil	6	0.163 ± 0.137efg
Canola oil	6	0.153 ± 0.117efg
Peanut oil	6	0.145 ± 0.167efg
Linseed oil	6	0.141 ± 0.025efg
Walnut oil	6	0.133 ± 0.121efg
Apricot kernel oil	6	0.125 ± 0.132efg
Cod liver oil	6	0.114 ± 0.106efg
Safflower oil	6	0.103 ± 0.139efg
Sesame oil	6	0.052 ± 0.058fg
Neat's foot oil	6	0.052 ± 0.017g
Mineral oil	6	0.009 ± 0.007g

[a]Acceptance ratio = (ants responding to fat or oil) / ants responding to Arrowhead Mills peanut butter oil. Means followed by different letters are significantly different at $P<0.05$ using Duncan's Multiple Range Test.
[b]tuna oil is vegetable oil removed from can of tuna.

The food acceptance tests was a modification of those described by Williams et al. 1980 and Vander Meer et al. 1988. In each test, the rearing cell contained 45 queens, 12,500 workers, and five grams of brood from a colony nester. After an hour of orientation, six foods in which one was always a

standard - three at each end of the rectangular chamber - were simultaneously given to six separate colonies. To avoid spillage or contamination, each food sample was placed on a 2 cm filter paper square which was then put on a 2.54 cm aluminum foil square; the rearing cells themselves centered in the test chamber (shoe box size storage boxes 33 cm X 18.4 cm X 10.8 cm high, Sterlite Corporation, 198-T Main St., Townsend, MA 01469).

The number of ants feeding on each food was recorded at 5 minute intervals for 30 minutes. If fewer than 100 ants were recorded the 30 minutes, the results were discarded. An acceptance ratio of each candidate food to the standard was calculated by dividing the number of ants responding to the candidate food by the number responding to the standard.

Data were analyzed by the general linear model (GLM) procedures (SAS Institute 1985, 433-506) with acceptance ratio as the dependent variable. Mean values were compared with Duncan multiple range test (Duncan 1955) at the $P = 0.05$ level.

Oil removed from the top of Arrowhead Mills peanut butter was the "peanut butter" standard in fat and oil acceptance tests. All peanut butter oils used in the acceptance tests were obtained by removing the separated layer of oil on top of the peanut butter. Raw wild honey was the standard in the sugar acceptance tests.

The following primary laboratory test evaluated the effectiveness of fenoxycarb. These tests were also conducted in Sterlite storage boxes containing one rearing cell with 3 fertile queens, 0.2g of brood, and approximately 500 workers. Fenoxycarb was tested at 0.01% to 5.0% solutions in peanut butter oil. The commercial bait, Maxforce Pharaoh Ant Killer, was used at the same weight of total bait as the fenoxycarb baits. Three colonies were treated per dosage; three control colonies were given the same bait quantity as the treated colonies but without the chemical. The colonies had access to all baits for 72 hrs after which time the colonies were returned to their normal laboratory diet. Weekly observations recorded the status of the colony (normal or abnormal), queens (size, laying eggs, and acting normal), mortality in workers and other castes, morphological abnormalities, type and quantity of brood, and first appearance of winged reproductives. The last two observations are especially important when evaluating insect growth regulators. Observations continued until the colony had died or completely recovered from the treatments effects. Colonies were considered normal after the queens began normal egg-laying, all brood stages were present and worker numbers were greater than pretreatment.

RESULTS AND DISCUSSION

Out of 29 fats and oils tested, lard was better accepted than the 28 other oils and fats (Table 1). Arrowhead Mills peanut butter oil, the standard, was significantly more acceptable than 19 oils but indistinguishable from 8 others.

Table 2 indicates that of 26 substances, 11 (all but one of these were types of honey) differed little from the standard (raw wild honey), but were significantly different from 14 others. Sourwood honey and orange blossom honey showed higher acceptance ratios than the standard.

TABLE 2. Acceptability of sugars to Pharaoh's ants, *Monomorium pharaonis*.

Sugar	No. colonies	Acceptance ratio[a]
Sourwood honey	20	1.017 ± 0.296a
Orange blossom honey	20	1.014 ± 0.188a
Raw wild honey	41	1.000 ± 0.000a
Saw palmetto honey	14	0.931 ± 0.220ab
Gallberry honey	4	0.911 ± 0.125ab
Buckwheat honey	5	0.871 ± 0.436ab
Tupelo honey	5	0.844 ± 0.540abc
Sunflower honey	10	0.804 ± 0.493abcd
Alfalfa honey	5	0.763 ± 0.430abcd
Brown rice syrup	21	0.747 ± 0.285abcd
Unsulphured molasses	4	0.746 ± 0.120abcd
Avocado honey	10	0.719 ± 0.321abcd
Barley malt	26	0.685 ± 0.246bcde
Light karo syrup	5	0.559 ± 0.170cdef
Mint apple jelly	17	0.542 ± 0.252cdef
Mint jelly	5	0.532 ± 0.221def
Molasses	4	0.397 ± 0.457efg
Maple syrup	10	0.351 ± 0.224fgh
Dark karo syrup	5	0.348 ± 0.149fgh
75% honey[b]	6	0.330 ± 0.250fghi
10% turbinado sugar[c]	6	0.177 ± 0.045ghi
10% confectioner's sugar[c]	6	0.152 ± 0.041ghi
10% dextrose[ce]	6	0.070 ± 0.026hi
0.9% NaCl[ce]	6	0.069 ± 0.015hi
10% glucose[de]	6	0.069 ± 0.023hi
Coke syrup	4	0.042 ± 0.029i

[a]Acceptance ratio = (ants responding per sugar) / (ants responding to raw wild honey). Means followed by different letters are significantly different at $P<0.05$ using Duncan's Multiple Range Test; [b](v:v); [c](w:v); [d](w:w); [e]hospital products.

The results of the primary laboratory evaluation tests showed that the most effective fenoxycarb concentrations in vegetable oil were 0.1%, 0.25%, 0.5%, and 1.0%. These four concentrations delayed the first appearance of sexuals longer than the other concentrations tested (Table 3). Also, 0.1%, 0.25%, and 0.5% gave the most dramatic reduction in brood during the 20 weeks; however, more than one treatment will be necessary because most of the colonies are now recovering from the affects of the IGR (Fig. 1). In general, concentrations higher than 1.0%, for example 2.5% and 5.0%, were not different than the controls and probably failed because of the chemical's repellency. Concentrations below 0.1%, for example 0.05% and 0.025% and 0.01%, caused no long-term effects, though a few colonies treated with these concentration had slight reductions in brood levels. However, these colonies quickly recovered from the effects and soon equaled the controls. After 20 weeks, the 0.25% concentration was slightly better than the 0.5% and 0.1%.

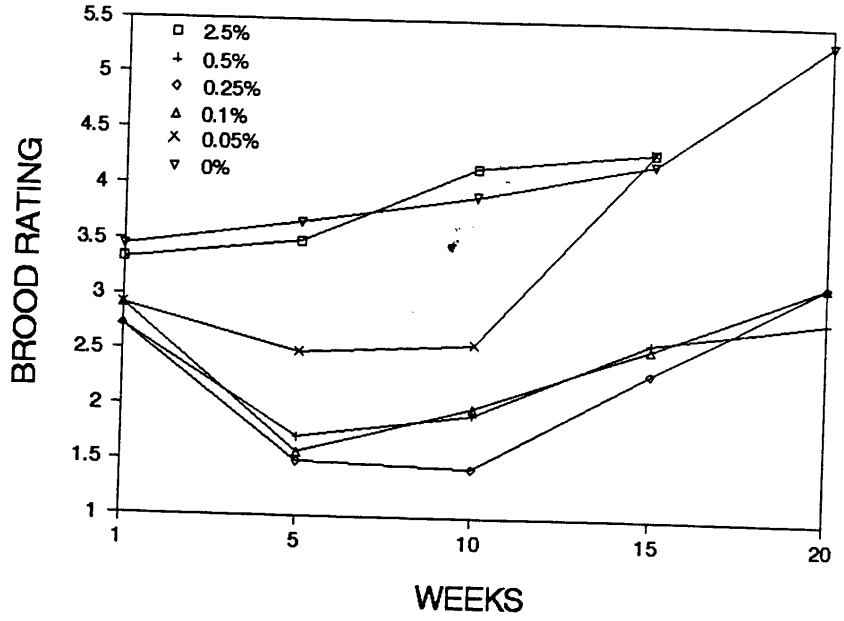

FIGURE 1. Effects of percent fenoxycarb on brood amount in Pharaoh's ant colonies. Brood rating of: 1 = 0.0115g brood, 2 = 0.0851g, 3 = 0.2752g, 4 = 1.3135g, 5 = 2.6205g, 6 ≥ 3.5g. All colonies began at brood rating = 3.

TABLE 3. First appearance of sexuals of Pharaoh's ant colonies treated with fenoxycarb.

Fenoxycarb % concentration	Colonies (N)	Appearance of sexuals[a] in weeks (X ± SD)
0.25	6	11.000 ± 4.1952a
0.10	10	10.900 ± 2.9609a
0.50	9	10.222 ± 3.6667ab
1.00	8	9.000 ± 4.5040abc
0.05	6	6.667 ± 2.8048bcd
2.50	3	6.333 ± 0.5774cd
5.00	3	5.667 ± 0.5774cd
0.00	18	4.944 ± 0.9984d
0.01	3	4.667 ± 0.5774d

[a]Means followed by different letters are significantly different at $P<0.05$ using Duncan's Multiple Range Test.

This concentration caused a more dramatic reduction in all brood levels and the appearance of intermediate castes which resembled small queens or large workers. Maxforce[R] effects were dramatic in the first two weeks, with most of the colony exhibiting high worker mortality, the loss of 1 or 2 of three queens and reduced brood levels. However, most treated colonies also returned to normal after 20 weeks. In most cases, like fenoxycarb, a single Maxforce treatment did not kill the pharaoh's ant colony.

The time required for the first appearance of winged reproductives usually indicates normal colony development. Table 3 shows that winged reproductives appeared within 4-5 weeks in normal colonies of test size. However, the effects of the 0.1, 0.25, 0.50, and 1.0% fenoxycarb significantly delayed the production of the winged reproductives in the treated colonies. The concentrations of 5.0, 2.5, 0.05, and 0.01% were not significantly different from the untreated control (normal) colonies.

CONCLUSION

This research developed laboratory procedures for testing baits for acceptance by pharaoh's ant, and for primary and secondary laboratory evaluation of bait formulation efficacy. Lard, peanut butter oil, and honey proved more acceptable to the pharaoh's ant workers than most other tested substances. Fenoxycarb at 0.5, 0.25 and 0.1 percent in Arrowhead Mills peanut butter oil caused dramatic colony brood reduction and significantly delayed production of the sexual (winged) forms in laboratory colonies. However, a single application of fenoxycarb and the other baits did not eliminate a small colony (ca 500 workers) of the pharaoh's ant; therefore, multiple applications are probably necessary to achieve complete control of these ant pests.

In the future, we plan to test the above formulations against larger laboratory colonies consisting of approximately 100+ queens, 5 grams of brood and more than 12,500 workers. Once we have determined the most effective fenoxycarb bait formulation and concentration against large laboratory colonies, the bait formulation will undergo a final evaluation. This involves field tests in infested dwellings.

ACKNOWLEDGMENTS

I am grateful to Karen Vail for excellent technical assistance. Appreciation is also given to W.A. Banks, J.A. Hogsette, J.P. Parkman, and J.T. Bridges for their advice and comments on the manuscript.

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