Field Tests of an Acephate Baiting System Designed for Eradicating Undesirable Honey Bees (Hymenoptera: Apidae)

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J. Econ. Entomol. 85(4): 1104–1111 (1992)

ABSTRACT Field evaluations were made of a baiting system designed for use by regulatory agencies in suppressing populations of undesirable feral honey bees, *Apis mellifera* L. (e.g., bees posing hazards [especially Africanized bees] and colonies infested with parasitic mites). Bees from feral or simulated feral (hived) colonies were lured with honey and Nasonov pheromone components to feeders dispensing sucrose-honey syrup. After 1–3 wk of passive training to feeders, colonies were treated during active foraging by replacing untreated syrup with syrup containing 500 ppm (mg/liter) acephate (Orthene 75 S). In four trials using hived colonies on Grand Terre Island, La., 21 of 29 colonies foraged actively enough at baits to be treated, and 20 of the 21 treated were destroyed. In the lower Rio Grande Valley of Texas (two trials at each of two sites), treatments killed 11 of 16 colonies (6 of 10 hived; 5 of 6 feral). Overall results showed that all 11 colonies that collected >25 mg acephate died, whereas 3 of 10 colonies receiving ≤25 mg survived. Delivering adequate doses required a minimum of ≈100 bees per target colony simultaneously collecting treated syrup. The system destroyed target colonies located up to nearly 700 m away from baits. Major factors limiting efficacy were conditions inhibiting foraging at baits (e.g., competing natural nectar sources and temperatures and winds that restricted bee flight).

KEY WORDS Insecta, *Apis mellifera*, pest management, acephate

FERAL HONEY BEES, *Apis mellifera* L., increasingly are of concern in the United States to the beekeeping industry, agricultural regulators, and the general public. Feral bees often need to be eradicated if they are a perceived danger when nesting or foraging in contact with humans. The impending Africanization of the feral gene pool in southern and coastal areas (Taylor & Spivak 1984, Taylor 1985, Rinderer 1986) is likely to lead to intensified calls for suppressing localized feral honey bee populations. Prudent, proactive elimination of undesirable colonies will help prevent serious stinging incidents. Minimizing the sensationalism that typically accompanies such incidents would help obviate alarmist reactions and associated detrimental effects on the beekeeping industry (Gary 1991).

USDA–ARS initiated research on honey bee abatement in 1987 explicitly for Africanized bee population management (Williams et al. 1988, 1989). Subsequent requests for abatement technology came from regulatory officials interested in controlling feral colonies infested with the parasitic mite *Varroa jacobsoni* Oudemans (J.L.W. & R.G.D., unpublished observations), indicating another potential use for abatement technology. An attempt was made in Czechoslovakia during 1982 and 1983 to slow the spread of *Varroa* by eliminating feral bees with paraquat-treated baits (Titera et al. 1987); the effort was reported to be moderately successful, demonstrating the potential utility of such methods.

A new technique for potential use in suppressing undesirable, localized populations of honey bees is a baiting system in which acephate is delivered to remote nests by foragers (Williams et al. 1988, 1989; Danka et al. 1989). This system, when coupled with knowledge of feral colony densities (e.g., Morse et al. 1990 and references therein) and feral population dynamics (e.g., Rubink et al. 1990 and references therein), may substantially improve the efficiency of controlling problematic bees beyond locating individual colonies for eradication. This article describes initial field efficacy tests of the acephate baiting system. The general test plan was to attempt to detect, then eradicate localized experimental populations that comprised feral and simulated feral (i.e., hived) colonies. Total colony numbers in test plots were varied to give densities found in several U.S. surveys (0.5–7

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colonies per square kilometer; see Morse et al. [1990]).

Materials and Methods

Baiting. Standardized bait stations (Danka et al. 1990) were distributed in grids within the test plots. Each bait station consisted of a bright yellow, 946-ml feeder cup that dispensed 50% sucrose syrup plus 10% honey (by vol) through 50 holes (1 mm in diameter) around the base. Honey and components of Nasonov pheromone were used as attractants. A 10-ml quantity of locally produced, mixed-source honey was smeared on the top and sides of the feeder. In the Louisiana tests, the pheromone mix (0.8 ml of 1:1 [citral–geraniol]) was dispensed from a piece of cellulose sponge inserted into an unsealed 1.5-ml polypropylene microcentrifuge vial. In the Texas tests, 200 μl of the pheromone mix was delivered from a sealed, 400-μl polyethylene microcentrifuge vial. Vials were secured directly beneath feeders, which were located on stands 1 m aboveground.

Baiting was initiated during periods of low nectar availability to facilitate attraction of bees to baits. Baits were checked for foraging activity or evidence of foraging (i.e., syrup depletion) at 1- to 7-d intervals. When depleted feeders were refilled they invariably were visited by honey bees within several hours. Syrup remaining in feeders was replaced when baits were checked, in part to avoid fermentation problems during hot weather. Visitation of baits by individual colonies was determined by vanishing bearings of departing foragers or by marking bees at baits, then searching hived colonies for marked bees. Baiting continued until feeder discovery by bees slowed, at which point some feeders were removed to help concentrate bee activity at fewer stations for treatment; feeders with greater activity were retained as they presumably indicated proximity to target colonies.

Necessary decisions before treatment included an estimate of the number of target colonies and if foraging activity was sufficient for predictable success. The standard protocol was to treat after instantaneous counts at a feeder showed visitation by a minimum of 100 foragers per target colony. Some treatments in the Texas tests purposefully were made when visitation was lower. For treatment, feeder cups containing untreated syrup were replaced quickly with preweighed feeders having 300 ml of syrup containing 500 ppm (mg/liter) acephate (Orthene 75 S; Chevron Chemical, San Francisco, Calif.). Foraging was monitored while bee visitation persisted (20–30 min), then feeders were removed and weighed to determine the amount of acephate collected. When multiple colonies were treated from one station, data on doses and foraging levels on a per colony basis were not obtainable. The degree of relationship between foraging activity and syrup removal was determined by linear correlation (Steel & Torrie 1980).

Managed colonies were monitored after treatment to determine if they functionally were destroyed (ultimate death of the queen and unsealed brood) or if they survived. These outcomes usually were apparent within a few days. Colonies were left in place for monitoring in Louisiana tests, but in Texas tests were moved into a screen enclosure (3 by 3 by 2 m) to prevent possible interference from other colonies. Feral colonies, which typically could not be thoroughly inspected, were considered destroyed if all signs of normal activity ceased within several weeks after treatment.

Louisiana Tests. Four trials were conducted from April to July 1989 on Grand Terre Island in Jefferson Parish. The barrier island is 2.4 square kilometers of predominantly saline marsh fronted by a low, washover terrace having mixed shrubby vegetation. Extensive baiting and searching preceding the tests revealed no feral honey bee colonies.

Hived colonies were placed in the centers of randomly chosen quadrants within 250-m-grid sectors on the island (Fig. 1). Colony size and density varied during the test as follows: trial 1, 6 colonies of ≈18,000 adult bees each; trial 2, 5 colonies of 18,000 bees each; trial 3, 3 colonies of 50,000 bees each; and trial 4, 15 colonies of 30,000 bees each. Population densities thus ranged from about one to seven colonies per square kilometer. All managed colonies used in tests had laying queens of mixed European stock, a brood nest that covered between five and seven combs, and ample food reserves and empty comb.

Bait stations were placed at each of 14 500-m-grid intersections in trials 1, 2, and 4 (Fig. 1). In trial 3, seven bait stations were placed at 1,000-m intervals along two transects 500 m apart (Fig. 1).

Texas Tests. Two trials were conducted at each of two sites covering 1 square kilometer in south Texas managed by the H. Yturria Land and Cattle Company. Testing occurred from November 1989 to January 1990 at the La Chata Ranch (8 km north of Raymondville, Willacy County); testing occurred from January to March 1990 at the La Joya Ranch (16 km north of La Joya, Hidalgo County). Study areas were comprised of ≈75% pasture maintained by scrub rolling and ≈25% mesquite-granjeno thicket. The La Joya site was drier and possessed flora more typical of deserts. Feral population densities were estimated to be 0.5 colonies per square kilometer at La Chata and 0.3 colonies per square kilometer at La Joya. Feral colonies were discovered or indicated by baiting and beelining (i.e., following vanishing bearings of bees departing feeders) or by occupation of honey bee swarm traps

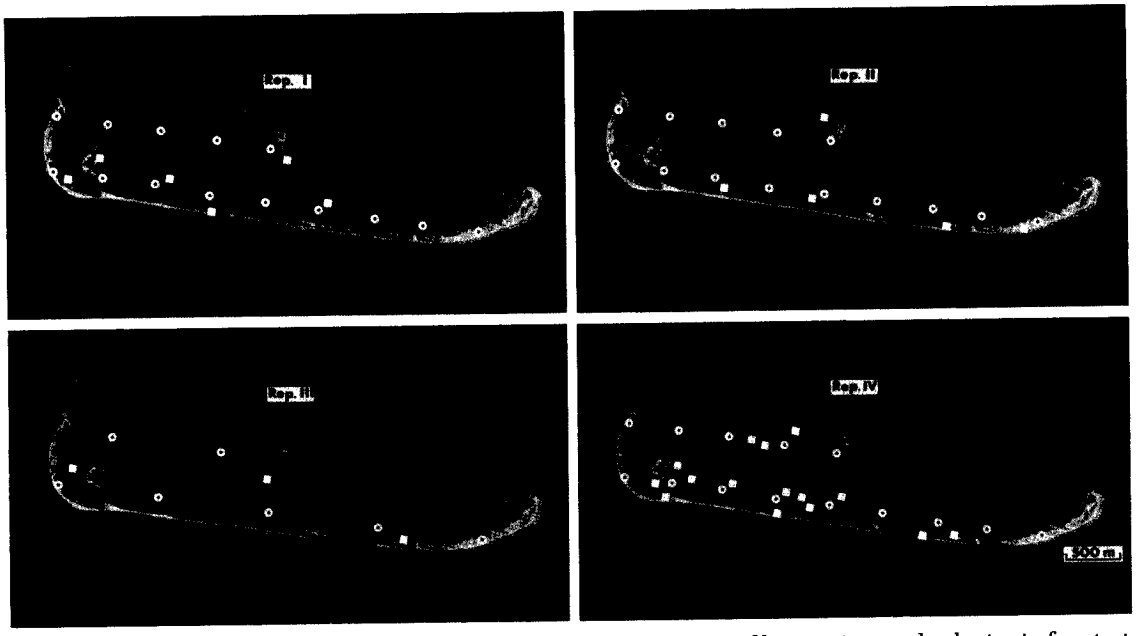

Fig. 1. Grand Terre Island (Jefferson Parish), La., showing positions of bait stations and colonies in four test trials. Circles represent bait stations, squares represent colonies.

or scout traps (Schmidt & Thoenes 1987; E.A.S., unpublished data).

Managed colonies were used in each trial to supplement the theretofore undetermined feral populations. Colonies were placed randomly within 250-m-grid sectors in the study areas (Fig. 2 and 3). Total population densities varied from two to six colonies per square kilometer as follows: trial 1, four managed colonies, two feral colonies on the plot, one feral colony located just off the plot and two unlocated feral colonies off the plot but visiting baits; trial 2, two managed colonies; trial 3, two managed colonies and one feral colony on the plot; and trial 4, two managed colonies. Number and positions of colonies were not revealed to persons who beelined and applied acephate treatments. To aid the blind approach to baiting and treating, managed colonies were partially hidden in brush and empty dummy hives were distributed to hinder visual recognition of test colonies.

Bait stations were established near each of 16 333-m grid intersections in the test plots, with positions adjusted for ease of visibility and access among thickets (Fig. 2 and 3).

Health of managed colonies in the Texas tests was monitored by censusing populations of adult bees (estimated combs covered) and brood (number of combs containing $\geq$10 cells of sealed brood), presence or absence of queen, flight activity (mean number of outgoing flights per minute), and defensiveness (sting counts from a standardized test of colony defensiveness [Collins & Kubasek 1982]). Colonies were monitored once before treatment and four times within 33 d after treatment.

Residues of acephate and its metabolite methamidophos were measured in dead bees and in samples of beeswax–honey matrix from

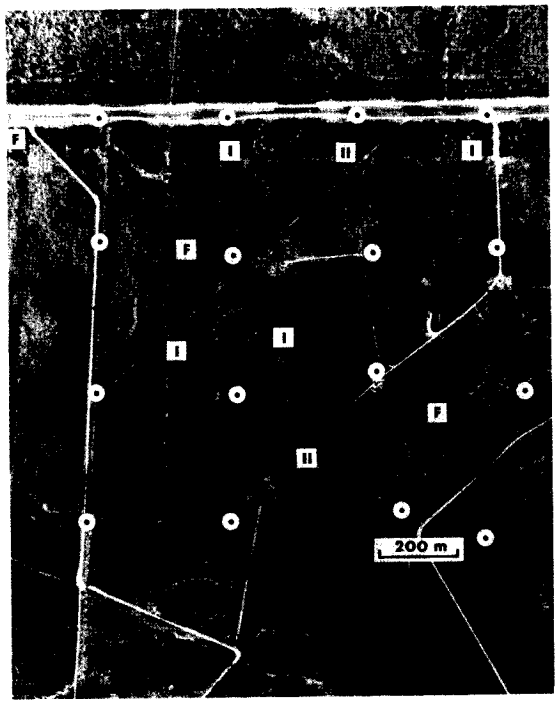

Fig. 2. Test plot on La Chata Ranch of the H. Yturria Land and Cattle Company (Willacy County), Texas, showing positions of bait stations and colonies in trials 1 and 2 of the Texas tests. Symbols are as in Fig. 1, with trial number or "F" (for feral) indicated on colonies.

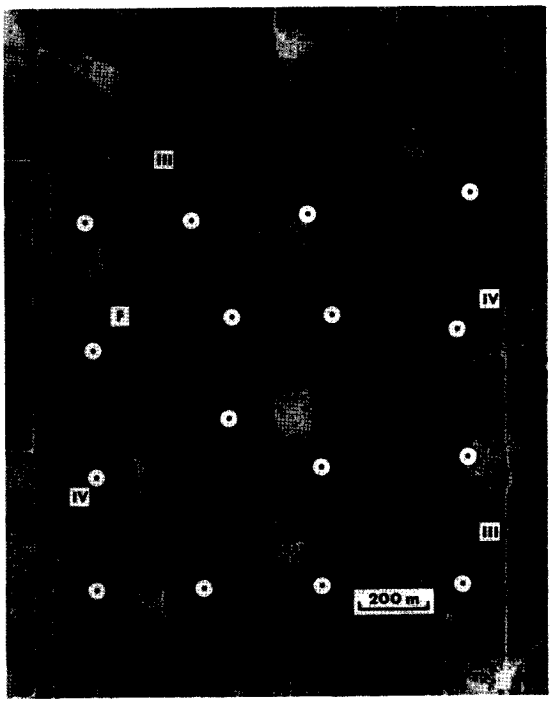

Fig. 3. Test plot on La Joya Ranch of the H. Yturria Land and Cattle Company (Hidalgo County), Texas, showing positions of bait stations and colonies in trials 3 and 4 of the Texas tests. Symbols are as in Fig. 1 and 2.

each of the 10 managed colonies in Texas. Samples of wax and unsealed honey (5- by 5-cm sections cut from five alternating combs) and dead adult bees (≈300) were taken two to three times within 1 mo after treatment. After a multiresidue extraction process (Luke 1983), residues were quantified using two different columns in a gas chromatograph equipped with dual nitrogen–phosphorus detectors. Details of residue extraction and quantification are available elsewhere (Danka et al. 1991).

Results

General. Under favorable baiting conditions, feeders usually were discovered by target honey bees within 1–3 d after they were set up. In both series of tests, 1–2 wk typically were required to achieve foraging activity sufficient for acephate treatment and to satisfactorily estimate target colony positions (Table 1).

Foraging responses during treatment were consistent. Bee activity declined for a few minutes after training feeders were replaced with feeders containing acephate, but visitation increased quickly and peaked ≈10 min after treated syrup was presented. Visitation began to decline rapidly ≈15 min after treatment was started, and ceased ≈30 min after treatment was started.

Louisiana Tests. Overall, 20 of 29 colonies (69%) were successfully destroyed on Grand Terre Island; only one of 21 colonies known to be treated survived (Table 1). Acephate baiting was nearly always successful when colony densities were low or moderate (0.5–2.5 colonies per square kilometer) and when nectar scarcity resulted in active foraging at the bait stations. Thus, in trials 1, 2, and 3, when both factors were favorable, 13 of 14 colonies on the island were treated, and 12 were destroyed. In trial 4, baits generally were visited less actively, apparently because of increasing nectar availability and high temperatures. Treatment decisions were

Table 1. Results of eight field trials that attempted to eradicate localized honey bee populations by presenting foragers with sucrose–honey syrup baits that contained 500 ppm acephate

Location[a]	Trial	Baiting period, d	Treatment date	No. colonies	No. treated	No. killed	Treatment distance, m, mean (range)	Milligrams acephate collected, mean ± SD (*n*)[b]	Max. bees per colony on feeder during treatment, mean ± SD[b]
Louisiana	1	11–12	17, 18 Apr.	6	5	5	154 (88–198)	18 ± 12 (5)	152 ± 90
	2	7– 8	5, 6 May	5	5	5	116 (88–198)	27 ± 5 (5)	178 ± 84
	3	8	31 May	3	3	2	477 (265–691)	31 ± 9 (3)	165 ± 44
	4	7–21	30 Jun., 19 Jul.	15	7–9[c]	8	376 (182–566)	28 ± 8 (3)	173 ± 56
Texas	1	9	8 Nov.	9[d]	9	8[e]	139 (82–223)	— (0)	—
	2	14[f]	26 Jan.	2	2	1	166 (163–168)	28 ± 11 (2)	108 ± 30
	3	19	27 Feb.	3	3	1	231 (163–360)	43 (1)	308
	4	8	17 Mar.	2	2	1	107 (90–124)	25 ± 0 (2)	102 ± 5

[a] Tests in Louisiana were conducted on Grand Terre Island from April to July 1989. Tests in Texas were conducted near Raymondville (trials 1 and 2) and La Joya (trial 3 and 4), from November 1989 to March 1990.

[b] Sample sizes for column 9 and 10 are equal but may differ from those in column 6 because treatments of multiple colonies per feeder are not included.

[c] Similar flight lines of departing foragers prevented exact determination of number of treated colonies.

[d] Includes four managed colonies, three known feral colonies, and two feral colonies off the plot and not located.

[e] Two feral colonies not located were presumed to be dead; they did not visit feeders for ≈11 wk after treatment.

[f] Twelve days of baiting were completed before tests were suspended between 28 November 1989 and 12 January 1990; 14 d of baiting indicated immediately preceded treatment on 26 January.

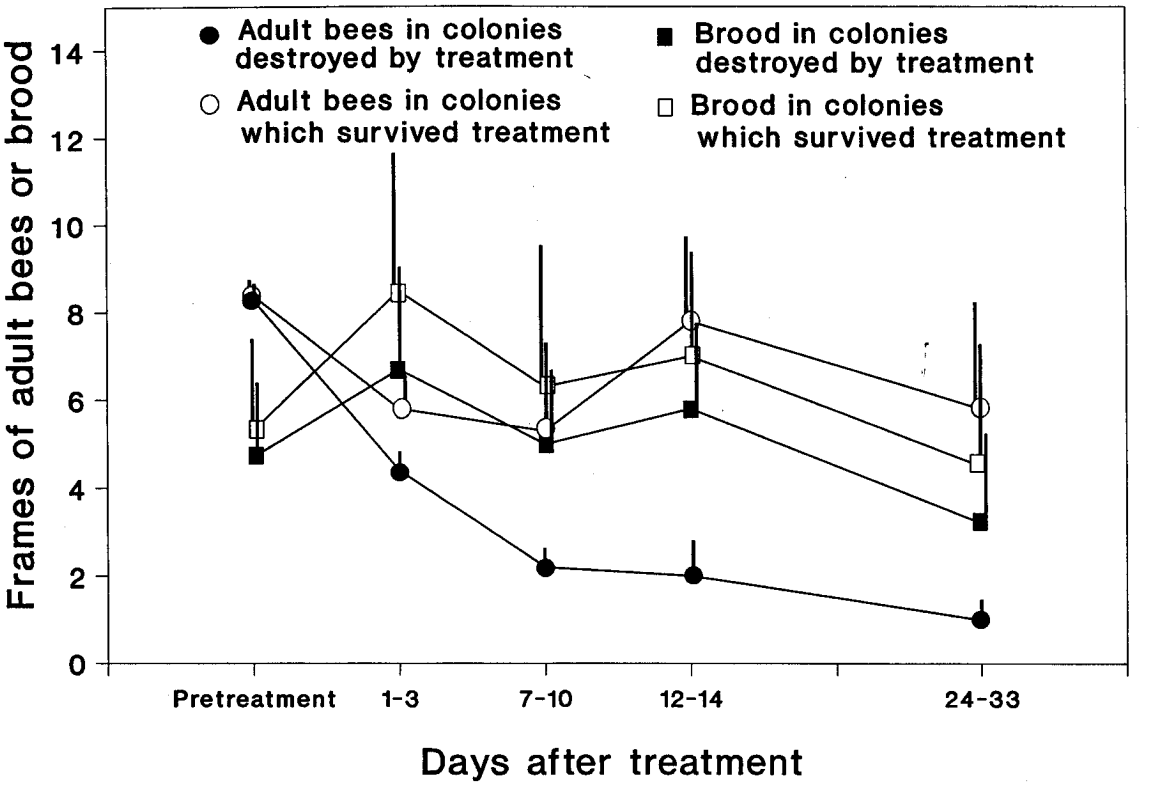

Fig. 4. Populations of adult bees and brood remaining in colonies destroyed by treatment (n = 6) and in colonies that survived treatment (n = 4) in Texas tests. Error bars represent 1 SEM.

complicated by the high density of colonies in this trial. At least 7 of 15 colonies were known to have been treated (similar flight lines prevented complete discrimination of target colonies at one bait station), and eight colonies were destroyed.

Colonies that were killed collected an average of 26 ± 10 mg acephate (mean ± SD, n = 16), and had a maximum of 164 ± 71 foragers on feeders during treatment. The colony that survived treatment had a maximum of 200 foragers and collected 23 mg acephate. A total of 526 mg acephate was collected by target colonies in Louisiana trials. Nontarget species did not visit treatment baits.

Texas Tests. Treatments in Texas produced more varied results, partly because some applications intentionally were made when foraging activity at baits was marginal. All 16 target colonies were treated and 11 (69%) were destroyed (Table 1). In trial 1, treatments killed or fatally weakened three of four managed colonies and all three feral colonies that had been located. The two unlocated feral colonies (indicated by beelines) probably also died; they failed to return to baits through January.

One of two managed colonies treated in each of trials 2, 3, and 4 was destroyed. The colonies that died collected 35 ± 9 mg acephate (n = 3) with a maximum of 179 ± 113 foragers at the feeder during treatment. Surviving colonies collected 23 ± 4 mg acephate (n = 2, trials 2 and 4) and had a maximum of 92 ± 8 bees foraging on baits. The feral colony present in trial 3 survived. It and the surviving managed colony were treated simultaneously from one bait station and had a combined maximum of only 82 foragers, which collected 21 mg acephate. A total of 573 mg acephate was collected by target colonies in Texas trials.

The effectiveness of acephate treatments was manifested quickly by changes in population levels and behavior. Populations of adult bees in destroyed colonies declined steadily after treatment compared with those in surviving colonies (Fig. 4). Brood amounts differed less sharply, with reduction in brood rearing occurring in both groups (Fig. 4). Flight activity at the entrances of destroyed colonies declined to zero or near zero within 30 min after treatment; a few flying bees were sometimes noted for several weeks. Flight also declined to zero in three treated but surviving colonies, but remained at pretreatment levels in the fourth. Stinging was not elicited from fatally treated colonies in nine defense tests conducted within 2 wk of treatment. Sublethally treated colonies stung in two of nine tests.

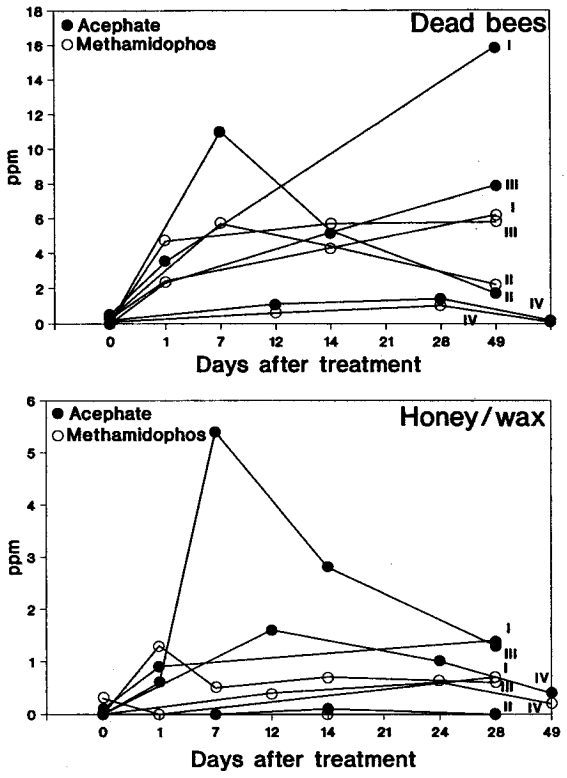

Fig. 5. Residues of acephate and methamidophos recovered from hived colonies treated in Texas tests. Roman numerals indicate trial numbers. Four colonies were sampled in trial 1, and two colonies were sampled in each of trials 2, 3, and 4.

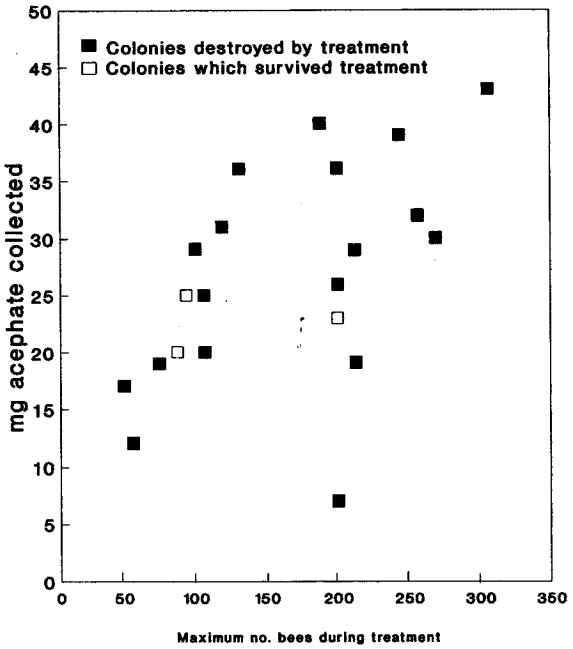

Fig. 6. Relationship of maximum numbers of foragers, total milligrams of acephate collected, and death or survival of 21 colonies for which all three categories of data were obtained.

Residues of acephate and methamidophos were higher in dead bees than in honey-wax, and acephate residues were higher than those of methamidophos (Fig. 5); similar trends were detected in a previous study (Danka et al. 1991). In dead bees, the highest acephate residue detected in any colony sample was 33.2 parts per million (ppm), with an overall mean maximum (based on maxima from 10 colonies) of 10.6 ± 9.2 ppm; the highest single methamidophos level was 14.7 ppm, with an overall mean maximum of 5.7 ± 3.9 ppm. In honey-wax matrix, the highest acephate residue detected in any colony sample was 8.6 ppm, with an overall mean maximum of 2.6 ± 3.0 ppm; the highest methamidophos level found was 2.6 ppm, with an overall mean maximum of 0.7 ± 1.0 ppm. Residue levels and decay trends varied greatly among colonies.

Two colonies of several thousand individuals each of *Brachygastra mellifica* (Say), a native polybiine wasp, were observed during trial 4. Wasps from each colony collected untreated syrup, but typically only when honey bees were not actively foraging. Up to four *Brachygastra* fed during treatment after bee visitation diminished; no evidence of poisoning was detected later at either nest. One to two individuals of several species of Diptera and Hymenoptera visited baits during treatment. Visits by nontarget species could have been avoided almost entirely by removing baits before honey bee activity ended.

Discussion

Successfully eradicating target honey bee colonies by using the acephate baiting system depended chiefly on having sufficient foraging during treatment. There was a strong positive relationship between maximum foraging activity of a colony and the dose of acephate consumed ($r = 0.522$, $n = 21$, $P = 0.015$). Dose and foraging measures in turn were good indicators of treatment success. All 11 colonies that collected ≥26 mg acephate died, whereas 3 of 10 colonies that collected <26 mg survived (Fig. 6). Fifteen of 16 target colonies died when foraging peaked above 100 bees at a feeder during treatment, whereas two of five colonies survived after foraging less actively (Fig. 6).

The trials thus demonstrated the critical requirement of achieving adequate foraging levels before presenting acephate-treated syrup. In actual applications of this system, the effort required to achieve sufficient foraging at baits will depend on the regulatory goals of the operation, on target colony density and distribution, and on prevailing environmental conditions. Simple

detection of target colonies depends minimally on luring bees to baits. Once this is accomplished, colonies may be located and acted upon individually, or baiting must continue and be intensified before acephate is dispensed. Care must be taken to present treated syrup only when colonies have at least 100 foragers (and preferably ≥200 foragers) on baits. Treating too few bees is insidiously counterproductive—not only do the sublethally treated colonies survive, but they typically cease foraging, thus preventing further action.

Sufficient foraging at baits sometimes was not attained during these trials. Primary causes were poor flight conditions (extreme temperatures or high winds), competing natural nectar sources, and baits too far from target colonies. Foraging waned under the hot, humid conditions in July on Grand Terre Island, and tests in Texas were interrupted several times by cold and windy weather. Warm, calm days provided optimal conditions for foraging, beelining, and treatment. Nectar availability generally was not a difficulty because the tests were planned to occur during nectar dearths. An exception was trial 4 in Louisiana; managed colonies were storing nectar at this time, and 7 of 15 colonies did not reach the 100-bee minimum even though all but one were observed to visit baits. Last, increased distance from colonies to feeders limited foraging activity. Most treatments were made from bait stations within 200 m of target colonies (Table 1), and foraging usually was markedly less beyond several hundred meters.

If acephate baiting is implemented, a major concern will be the applicator's ability to discriminate between target and nontarget, managed honey bee colonies. The system is being developed for use in limited circumstances by trained regulatory personnel. Sites of expected use (e.g., high-use outdoor recreational areas) are areas where managed colonies are absent or are subject to removal or closure during treatment. Careful consideration clearly must be given to drawing bee abatement protocols that coordinate efforts between regulators, beekeepers, and landowners. The limiting effect of distance on baiting success suggests that nontarget colonies outside a protective buffer of at least 1 km surrounding a treatment plot would be safe from unintentional treatment as long as minimum foraging thresholds for treatment are maintained and directions of departure angles of foragers are considered to verify that bees are from the target plot.

Field test experiences indicate that practical use of the treatment system will vary with the specific circumstances of each use and that correct timing of baiting needs to be carefully considered in different places. In many temperate zones, for example, autumn treatments are potentially ideal for three reasons. First, honey bees often are inclined to forage intensively on exposed sugar or honey during warm periods in autumn. Second, vulnerability is increased because brood production is absent or minimal and adult populations are declining. Finally, colonies that are only debilitated at this time will face the added stress of winter.

The acephate baiting system is somewhat cumbersome but has several noteworthy attributes if regulatory suppression of pestiferous honey bees is needed. First, having to locate colonies individually is unnecessary. Second, by exploiting the recruitment behavior and trophallaxis of honey bees, treatments are effective using relatively small amounts of insecticide (Danka et al. 1991). For example, the average successful colony dose (30 mg acephate) is 1/150 the maximum labeled use rate of acephate against the red imported fire ant, *Solenopsis invicta* Buren (one tablespoon Orthene 75 S—4.5 g [AI]—per colony). Third, the system is highly species specific. Acephate is presented only when honey bees and no other species are active at feeders; nontarget species routinely are excluded from feeders when bee activity is great (≥200 bees per feeder). Collectively, these attributes suggest that acephate baiting is a potentially useful tool for abating undesirable honey bees.

Acknowledgment

Art Cavasos, James Baxter, Daniel Winfrey, Gerard Perrone, and J. Anthony Stelzer provided invaluable technical assistance in the field or in preparing graphics. Daniel Butler of the H. Yturria Land and Cattle Company generously permitted us to conduct research on the company ranches. We thank the personnel of Lyle S. St. Amant Marine Laboratory, Louisiana Department of Wildlife and Fisheries, for the use of their facilities. The Louisiana Geological Survey provided information and maps of Grand Terre Island. Aerial photographs of the Texas study sites were provided by the USDA-ARS Remote Sensing Unit, Weslaco, Tex. Hachiro Shimanuki, Jose Villa, Adrian Wenner, Fred Whitford, and Peter Witherell kindly reviewed the manuscript. Texas portions of the study were funded by the USDA Pilot Test program. This research was completed in cooperation with the Louisiana Agricultural Experiment Station.

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Received for publication 8 August 1991; accepted 4 February 1992.