Original Research

Efficacy of bait hives in relation to their spatial distribution

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INTRODUCTION

Humans have attracted honey bee swarms to artificial cavities for at least 4,000 years (Crane 1983). The design of different artificial cavities used to attract swarms depended largely on available materials in a given region at a particular time. Recently, the objective of swarm capturing has been modified to monitoring and destroying advancing Africanized honey bee swarms in Mexico and the United States. Over 40,000 plastic-covered cardboard boxes baited with Nasanov analogues were in place at the peak of Africanized bee control activities in Mexico in late 1988. Currently, hundreds of bait hives are located in Texas, Louisiana, New Mexico and Arizona for monitoring the advance of Africanized bees into the United States.

The advance of Africanized bees through Mexico and into the United States suggests that the use of bait hives as a single technique is not adequate for area-wide eradication of honey bees. However, some practical applications for bait hives still seem feasible, such as protecting high-risk urban areas, high-use outdoor recreational facilities and queen mating zones from occupation by undesirable swarms. Also, the more traditional capture of swarms for increase of colony numbers by beekeepers might be made more cost-effective with improved bait hives.

To provide guidelines for density and placement, it is necessary to understand how swarms respond to bait hives located at different distances. The pioneering work by Lindauer (1951, 1953) showed that nest cavity selection is a well-organized process involving scouting, evaluation of different cavities, and coordinated movement of the swarm. His work, and later work by Seeley and Morse (1978), clarified the physical characteristics of nests evaluated in the selection of cavities by scouts. More recently, the addition of synthetic Nasanov gland components to bait hives has been shown to greatly enhance their occupation by swarms in very different ecosystems (Free *et al.* 1981, Lesher and Morse 1983, Kigatiira *et al.* 1986, Schmidt and Thoenes 1990a). Cavities with appropriate physical characteristics and baited with orientation pheromones appear to be very attractive, but the proportion of swarms at given distances that are captured has not been quantified.

Investigations of distance "preferences" of swarms have produced very disparate results. Consensus dances prior to swarm dispersal indicated that most swarms moved from 500 to 1,500 m to unbaited cavities in urban Munich (Lindauer 1951) and rural Ithaca (Seeley and Morse 1977). However, in studies by Jaycox and Parise (1980, 1981), artificial swarms of Carniolan and Italian origin moved preferentially to empty hives at distances of 200 m or less. The effects of pheromones on distance attraction have also produced unclear information. Witherell & Lewis (1986) did not recapture any of the 4 swarms released at 1/4 mile (2 swarms) and 1/2 mile (2 swarms) from a stand of 28 bait hives. Schmidt and Thoenes (1990b) estimated that they recaptured 90% of the swarms, which issued from a 38 colony apiary in a total of 48 bait hives arranged in concentric rings at distances between 50 and 1,000 m.

In the tests reported here, the most attractive type of bait hive and pheromone combination known (wood-

ABSTRACT

The responses of swarms to artificial 31 liter wood-pulp cavities baited with citral, geraniol and nerolic/geranic acid were investigated in different tests conducted during the swarming seasons of 1989, 1990 and 1991 near Baton Rouge, Louisiana. Observations on dances and actual captures of relocated and artificial swarms showed that they scouted and occupied natural and artificial cavities at a wide range of distances (50 m to 10 km), but only with a high probability discovered single bait hives at 100 m or less from the swarm. Bait hives had to be discovered before they were occupied, and in most cases once a bait hive was discovered it was occupied. These data indicate that small numbers of bait hives will not be discovered by all swarms in an area, and are only useful as monitoring tools. A higher density of bait hives in dispersed or regular distributions could have applications for localized control of undesirable swarms.

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KEY WORDS

Apis mellifera, bait hive, honey bee, Hymenoptera, nest, swarming

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BIOGRAPHICAL SKETCH

José D. Villa has studied the behavior of Africanized and European bees in Columbia, Venezuela, Costa Rica and Mexico. He also conducted research on the ecology of European bees in Louisiana and the use of bait hives. He currently works as an entomologist conducting research on tracheal mites, pollination and Africanized bee managment.

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pulp bait hives baited with citral, geraniol and nerolic/geranic acid) was used. Swarms were placed at different distances from bait hives in different spatial arrangements in order to test the proportions of swarms attracted and captured.

MATERIALS AND METHODS

Tests were conducted in East Baton Rouge parish, Louisiana during the swarming seasons (March to June) of 1989, 1990 and 1991. Three types of swarms were used in the tests: 1) Relocated swarms, shaken on stands or trees after being collected from sites reported by local residents; 2) Artificial swarms, about 1.5 kg packages shaken out of colonies, left queenless and fed sugar syrup overnight, shaken on stands and given a mated queen the next morning; 3) Natural swarms, issued from colonies and observed *in situ*.

Test 1: Twenty bait hives around a central apiary—In 1989, 20 bait hives were arranged as sets of four at each of five distances from a central apiary (50, 100, 200, 400 and 800 m; see Fig. 1). Disturbed and secondary growth bottomland forest covered about 55% of the area within 2 km from this central apiary; the remaining area included pastures and crops with large trees along fencelines. Nesting cavities probably were not limiting given the presence of tree species of sizes known to be occupied by bee colonies in other study sites.

Cylindrical bait hives (31 liters) were attached with wire to main tree branches about 3m from the ground. Two sealed thin-walled polyethylene tubes with 30 μl of citral (mixture of [E] and [Z] isomers), 30 μl geraniol, and 30 μl of nerolic/geranic acid (approximately 30% nerolic acid and 60% geranic acid) were suspended from the inside wall of each bait hive. Queens in colonies showing preparation for swarming at the central apiary were marked with numbered plastic disks, and about 1/5 of the workers were lightly sprayed with dilute water-soluble latex-based paint. Five swarms obtained from other sources were placed at the central location at different times. Each bait hive was inspected at least once a week from April 1 until May 22 and all captured swarms were removed and the bait hive replaced with a new bait hive and pheromone tubes. The colonies with marked queens were inspected for the presence of queens at the end of the test.

Test 2: Swarms at different distances from a bait hive station—A different experimental arrangement was used in 1990 and 1991 to test the responses of individual swarms at different distances from a single location of bait hives. A central bait hive location was established and swarms were relocated to stands at different distances from this center. The number of pheromone-baited hives suspended at the central cluster of trees varied from 1 to 4 through the experiment to maintain as many bait hives as swarms on stands. The area around this center was similar to the one described for Test 1, except that the area in forest was smaller (40% of an area of 2 km radius) and housing developments were found in about 10% of this area and to the north of it. Relocated swarms were used as they became available through telephone reports; they were randomly assigned to selected distances from the central bait hive location (50, 100, 200, 300 and 800 m). Later in the season, artificial swarms were placed simultaneously at each of the four closest distances, and sets of swarms were monitored until all swarms had moved. In all cases the queens were marked with a numbered color disk and all captures in the bait hives were inspected for the presence of marked queens. Captured swarms were moved to apiaries at least 2 km away from the capture site.

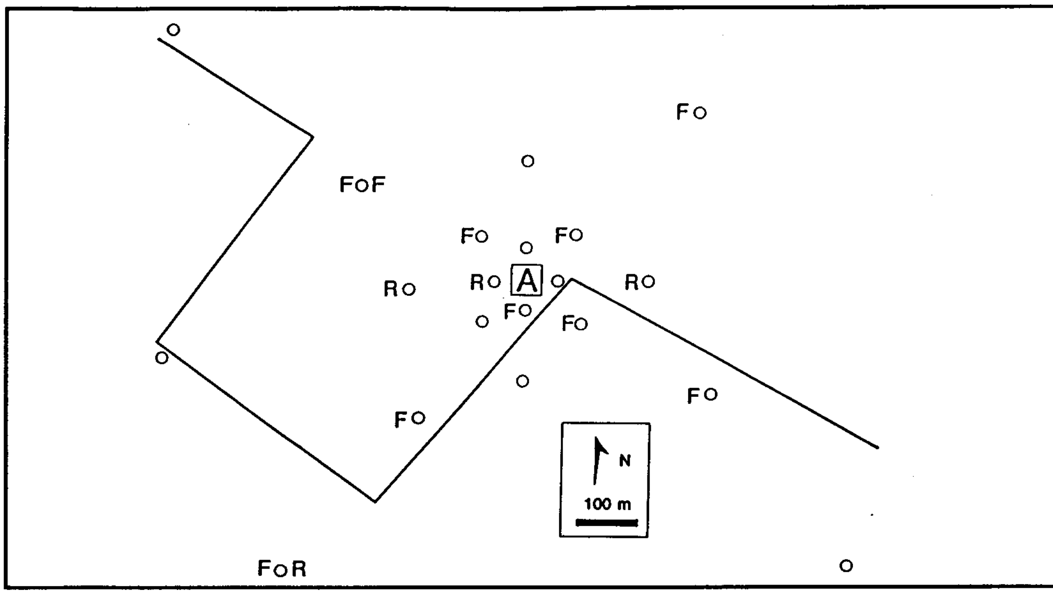

Figure 1. Position of bait hives (circles) around a central apiary (A) and types of swarms captured in each of the bait hives in Test 1 (R indicates four out of five relocated swarms that were captured; F indicates other captured swarms that probably came from feral colonies in the area, given that apiary colonies did not swarm). The area to the north of the solid line was forested; the area to the south was in pastures but had fencelines with large trees and isolated trees in the pastures.

Dances of workers on the surface of swarms were decoded as to distance and direction. Observations were not made systematically; more observations were made on swarms where dances indicated a consensus on cavity choice, or where the departure of a swarm was imminent. The time from when a swarm was installed until it departed was calculated whenever possible and converted to the amount of daylight hours. This value estimates the time required by each swarm to search, find and move to an adequate location.

The test in 1991 differed from that in 1990 in two ways. First, clearing of a treeline forced a change of the central location for bait hives to a clump of trees 200 m to the west. Second, the prevalent use of only citral and geraniol (without nerolic/geranic acid) in regulatory programs suggested that this combination should be tested for distance attraction.

Test 3: Responses of issued natural swarms to bait hives—Further tests were conducted in 1991 with natural swarms that had not been relocated to evaluate the attraction to bait hives after the initial movement out of parent colonies had occurred. In five instances, a single bait hive was located between 10 and 20 m from swarms that had been reported on their property by residents.

RESULTS

Test 1: Twenty bait hives around a central apiary—There was no evidence of swarms issuing from the colonies that had been selected as possible swarm sources in the central apiary. No marked queens or painted workers were recovered in bait hives, and all marked queens were still found in the colonies. To compensate for the lack of swarming in the apiary, five swarms were relocated to trees in the central apiary at different times. Four out of these five swarms shaken on trees in the central apiary were recaptured in the bait hive grid (one at 50 m, two at 200 m, and one at 800 m, Fig. 1). Swarms did not show any pattern of directional preference. Ten additional swarms of unknown origin were captured during this observation period (Fig. 1). Twelve out of the 20 bait hive locations captured swarms (two bait hive locations captured two swarms each). There was no pattern in the direction of occupation of the bait hives that might have suggested the origins of these other swarms.

Test 2: Swarms at different distances from a bait hive station—Capture success was clearly influenced by the distance between a bait hive and a swarm at a given distance from it (Table 1). In the experiments in 1990, both relocated and artificial swarms at 50 m had a high probability of being captured, and this probability rapidly decreased with distance so that swarms at 300 and 800 m were never caught in the central bait hive location.

The capture of swarms was much lower in 1991

Table 1

Number of swarms presented with a bait hive at a given distance and number captured in the bait hive (Test 2). Data are presented for three kinds of swarms in two years and with different pheromones.

Type of Swarm (Pheromone)	Bait Hive Distance	Number of Swarms Tested	Number of Swarms Captured
Relocated - 1990	50 m	7	5
citral, geraniol,	100 m	7	2
nerolic acid	200 m	7	1
	300 m	6	0
	800 m	4	0
Artificial - 1990	50 m	4	4
citral, geraniol,	100 m	4	2
nerolic acid	200 m	4	0
	300 m	4	0
Relocated - 1991	50 m	7	4
citral and geraniol	100 m	7	0
	200 m	6	0

when nerolic/geranic acid was not included in the pheromone blend and a new location was used for bait hives. However, the same pattern of high captures at the closest distance persisted.

Readings of dances indicated that scouts were discovering alternative sites to the bait hives at distances ranging from 150 m to around 10 km (unpublished observations). In many cases, scouts from swarms that later occupied bait hives were observed dancing on the swarm surface, indicating the location of the bait hive. There was only one case in which dances had been seen, indicating the bait hive, and later the swarm moved to another unknown location. In all cases where bait hives had been checked at least an hour before occupation, intense scouting activity was observed at the bait hive.

The number of daylight hours from installation to departure by the 47 swarms observed in 1990 varied considerably (range 4-60 daylight hours), but on average did not differ between artificial and relocated swarms. There also was no difference between the time spent scouting by swarms that were captured in bait hives (mean = 20.5 daylight hours, n = 14) and swarms that moved to unknown locations (mean = 20.5 daylight hours, n = 33).

Test 3: Responses of issued natural swarms to bait hives—Even though there was a high probability of capturing an artificial or relocated swarm with a bait hive at 50 m, the placement of a bait hive at a distance between 10 and 20 m from swarms reported by the public did not have the same success. Only one swarm out of five was captured when this was attempted.

DISCUSSION

The results of these tests show that the occupation of bait hives by swarms is a hierarchical process. An initial necessary step is the discovery of the bait hive by scouts. The discovery probability is influenced by distance from the swarm (or the distance of a searching scout's flight path to a bait hive). After the first discovery by a scout, many other scouts need to visit the bait hive before swarm movement. Provided that a bait hive presents an adequate combination of physical characteristics, once it is discovered by scouts it is likely to be occupied. It is therefore improbable that bait hives can modify the choices of a swarm already in motion to a specific location, unless it is very close to the intended destination of the swarm.

The rapid decline in capture success with distance away from the bait hive, as observed in Test 2, is probably a consequence of two closely related spatial and physical equations. First, as the distance a scout flies away from a swarm increases, the area to be scouted for prospective cavities at a given distance increases. This increased area to be searched reduces the probability of finding an individual site. Second, the dilution of pheromone from the bait hive with distance also will make the probability of discovery depend on the distance of a scout to the bait hive. These two phenomena probably act to create this very sharp decrease in capture with distance, which is largely an effect of discovery probability.

The apparently lower capture of swarms in the 1991 distance test could have been caused by the absence of nerolic acid in the lures. The importance of this component was verified in more recent tests (Schmidt and Thoenes 1992, Winston *et al.* 1993). Unfortunately in the 1991 test, the effects of the pheromone were confounded with season and a different location of the bait hives.

Given the variability of scouted distances and movement distances observed in these tests, the genetically defined movement distances suggested by Jaycox and Parise (1980, 1981) for different races of bees are not very evident. Although many of the swarms used in these tests likely had Italian origins, the results suggest that availability of nesting cavities, weather, and the random discovery of an adequate cavity may greatly influence movement distance. Alternatively, the current genetic composition of local bees could be very different from those used in experiments by Lindauer (1951), Seeley and Morse (1977), and Jaycox and Parise (1980, 1981).

One unknown component of the efficacy of bait hives is their ability to compete for swarm preference with natural cavities. If there is no inherent preference for bait hives over natural cavities once they are discovered, the only advantage that bait hives have is their pheromonal attraction to scouts. If it is demonstrated that bait hives are "preferred" over discovered natural cavities, then the need for a high number of bait hives in an area might need to be reevaluated. With the absence of this information, it is more logical to assume that swarms will move to any discovered cavity that has certain basic physical attributes regardless of whether it is "natural" or artificial.

The three tests described in this experiment demonstrate that the placement of bait hives in an area does not guarantee that all swarms in the vicinity will be attracted to them. Even with a relatively high density of bait hives (Test 1), not all swarms are captured. Given the decline in capture probability with distance (Test 2), it is necessary to place hives in a dispersed arrangement or in a regular grid to maximize the possibility of attracting the highest number of swarms in a locality. A linear bait hive arrangement along main roads or a cluster of bait hives will have a lower probability of attracting a high proportion of the swarms in an area. To increase the probability of capturing swarms from an apiary, bait hives should not be placed once swarms are issuing, but instead they should be placed earlier in the swarming season, and it is probably best to place pheromone-baited hives within 100 meters of the apiary and not at what is thought to be a genetically predetermined movement distance.

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LITERATURE CITED

Crane, E. 1983. *The archaeology of beekeeping.* Cornell, Ithaca, NY.

Free, J. B., J. A. Pickett, A. W. Ferguson, and M. C. Smith. (1981) Synthetic pheromones to attract honeybee (*Apis mellifera*) swarms. *J. Agric. Sci.* 97: 427-431.

Jaycox, E. R. and S. G. Parise. 1980. Homesite selection by Italian honey bee swarms, *Apis mellifera ligustica* (Hymenoptera: Apidae). *J. Kans. Entomol. Soc.* 53: 171-178.

______. 1981 Homesite selection by swarms of black-bodied honey bees, *Apis mellifera caucasica* and *A. m. carnica* (Hymenoptera: Apidae). *J. Kans. Entomol. Soc.* 54: 697-703.

Kigatiira, K. I., J. W. L. Beament, J.B. Free, and J. A. Pickett. 1986. Using synthetic pheromone lures to attract honeybee colonies in Kenya. *J. Apic. Res.* 25: 85-86.

Lesher, C., and R. A. Morse. 1983. Baits to improve bait hive attractiveness to honey bees. *Am. Bee J.* 123: 193-194.

Lindauer, M. 1951. Bienentänze in der schwarmtraube. *Naturwiss.* 38: 509-513.

______. 1953. Bienentänze in der schwarmtraube (II). *Naturwiss.* 40: 379-385.

Seeley, T. D. and R. A. Morse. 1977. Dispersal behavior of honey bee swarms. *Psyche* 84: 199-209.

______.1978. Nest site selection by the honeybee. *Insectes Sociaux* 25: 323-327.

Schmidt, J. O. and S. C. Thoenes. 1990a. Honey bee (Hymenoptera: Apidae) preferences among artificial nest cavities. *Ann. Entomol. Soc. Am.* 83: 271-274.

______.1990b. The efficiency of swarm traps: what percent of swarms are captured and at what distance from the hive. *Amer. Bee J.* 130: 811-812.

______.1992. Criteria for nest site selection in honey bees (Hymenoptera: Apidae): preferences between pheromone attractants and cavity shapes. *Environ. Entomol.* 21: 1130-1133.

Witherell, P. C. and J. E. Lewis. 1986. Studies on the effectiveness of bait hives and lures to attract honey bee swarms - a survey tool for use in Africanized honey bee eradication programs. *Amer. Bee J.* 126: 353-361.

Winston, M. L., K. N. Slessor, W. L. Rubink, and J. D. Villa. 1993. Enhanced pheromone lures to attract honey bee swarms. *Amer. Bee J.* 133: 58-60.