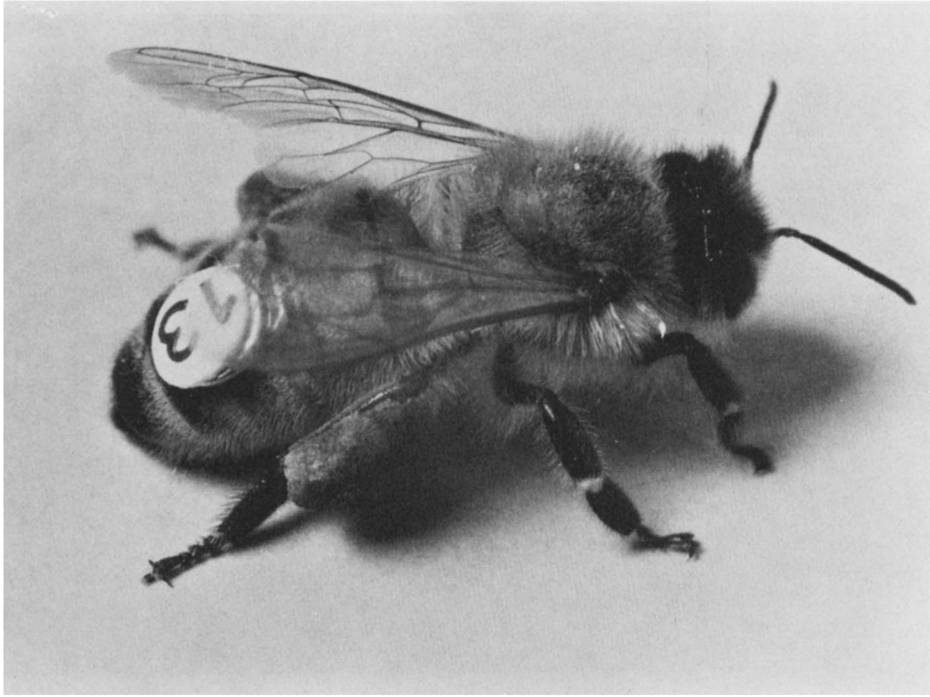

Worker honeybee with ferrous metal tag glued to abdomen. Pollen load is visible on hind leg.

A new and recap for evalu poll

A new tagging and magnetic recapture system permits large-scale studies of the factors that apparently attract bees and regulate their distribution and foraging activities. These data may confirm or disprove many theories proposed from less detailed past research, and hopefully, lead to new concepts concerning pollination. The net result may be greater control over the foraging activities of honeybees and greater efficiency of utilization for pollination purposes and honey production.

MUCH OF CALIFORNIA'S AGRICULTURE depends upon the pollinating activities of honeybees. Each year approximately $300,000,000 worth of California orchard and field crops require bee pollination.

The need for honeybees is increasing because of the expanding acreage of many agricultural crops requiring insect pollination. An acute shortage of bees for pollinating the increased almond acreage is developing into a major problem. A further complication is the reduction of native populations of other insect pollinators in many areas because of certain cultural practices and pesticide usage. Another problem with native pollinators is that they frequently are not available at the time they are needed.

In general, the honeybee is the primary insect pollinator because economical methods have been developed over the years for the propagation of bees in adequate populations to do the pollination job. Furthermore, these populations are easily distributed to areas where and when they are needed.

Even though honeybees are known to be essential pollinators, the research job of demonstrating, defining, and enhancing honeybee pollination efficiency is not an easy one. In a typical production area, there may be literally hundreds of beehives near the area that needs pollination. Yet, insufficient bee populations may actually reach the target field. Research on pollination problems necessarily involves determining the quantity of bee foraging activity in the target areas, as affected by: (1) the distance bees must fly to reach the areas; and (2) the numbers of hives necessary to provide an adequate population of foragers.

How much bee activity is needed for effective pollination? Measuring pollination quantitatively is not so straightforward as, for example, determining fertilizer rates—primarily because it is not possible to control the quantity or quality of foraging activities of bees in specific treatment plots within a field or orchard. Bees range far and wide and tend to be distributed according to the distribution of available nectar and pollen. Honeybees have been known to fly more than five miles to reach food. This extreme range was observed where hives were placed in desert conditions and no other food was available. Yet the typical flight range is probably much shorter in most agricultural areas. The major problem in evaluating honeybee pollination effectiveness is determining the foraging range and distribution patterns of bees as a means of establishing where the "pollination treatment" is "applied." To complicate matters further, the numbers of foraging bees per area, and the duration of activity, also must be known in order to establish the quantitative aspects of the "pollination treatment."

New method

During the past year a new method to trace the foraging activities of honeybees has been developed so that foraging distribution maps can be prepared. Bees are captured individually while foraging in the field. In most cases, an insect net is used. However, when bees are sampled from trees, a portable vacuum cleaner with a long pick-up arm is used. Captured bees are anesthetized by exposing them to carbon dioxide for approximately 10 seconds. This treatment immobilizes the bee and permits the operator to handle it without getting stung.

While the bee is anesthetized, a tiny metal identification tag (3/32 inch diameter; 1/10,000 inch thick, and 10 mg weight) is attached to its abdomen (dorsally) by a special elastic glue (photo 1).

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NORMAN E. GARY

The ferrous metal tags are numbered by color codes or by tiny numbered plastic discs glued piggy-back on the metal discs. After each bee is tagged at specific sample plots within the target field crops, it is released immediately. After a few moments it revives and within an hour the bee normally has returned to its hive, usually within a four mile radius (50 square mile area). The tagged bee must be recaptured at its hive before a flight distribution map can be prepared.

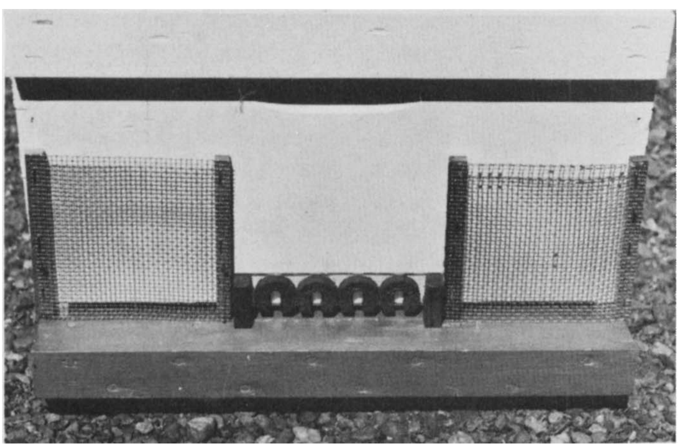
In previous methods of mapping foraging distribution, all hives within the area had to be opened and searched visually for marked bees, sometimes identified by tiny paint marks or plastic labels glued to the body. This extremely unpleasant task frequently required the examination of hundreds of hives, each of which usually contains between 20,000 and 50,000 worker bees. Besides receiving a few stings during the operation, a researcher can find such a task to be extremely time-consuming. Many of the marked worker bees actually died of old age before they could be located. The recapture success was too low to make the method feasible.

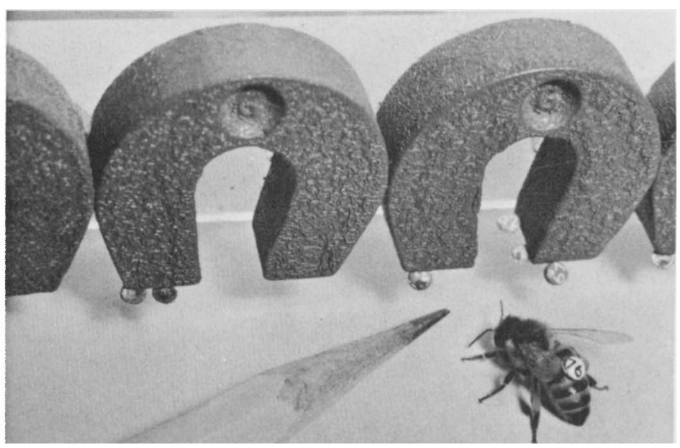
In the new method, tagged bees return to their hive where they must crawl under a magnetic trap attached to the hive entrance (see photos). At this point the magnet attracts the tag and jerks its captive bee off its feet. Both tag and bee are stuck fast to the magnet until the bee can twist free from the tag. Then the bee continues its normal activities and the tag remains on the magnet as evidence of recapture. The system allows thousands of bees, tagged in many areas, to be identified when their tags are collected automatically at hundreds of hives within several miles of the initial bee capture area. These tags accumulate on the traps for the duration of the experiment, and hives do not have to be opened, unless other data are needed on the condition of the colonies.

As usual in such research procedures, the quantity of information may not be apparent at first. The initial capture point of the bees helps determine which crops they prefer. It may also reveal important differences in the attractiveness of various varieties of the same crop. Furthermore, the initial capture location pinpoints the bees' preferred foraging area, reveals the distance that bees can be attracted to various crops, and documents the time of foraging activity—which may be related to transient weather variables or other time-related events. When the recapture location becomes known, it is possible to construct detailed maps of "bee traffic" from apiaries to foraging areas or fields that need pollinating.

One of the most valuable kinds of data made possible by the magnetic recapture method concerns an analysis of the genetic bias in bee colonies, as it affects their foraging behavior. The ability to

Magnetic honeybee trap (photo to left) contains four 1-oz horseshoe magnets, shown in position at hive entrance. "Escape" screens on either side are spaced ¼-inch from hive wall and permit bees to exit. Returning tagged foragers are diverted to the trap, and enter directly below the magnets. Tagged bee is approaching magnetic trap at hive entrance (photo to right). Previously recaptured tags are visible on the 1-oz horseshoe magnets.





trace large numbers of foraging bees to their respective hives makes it possible to associate various genetic stock with its performance characteristics. Several research workers have demonstrated during the past decade that honeybees can be selected for crop preference, and this trait can be enhanced by controlled breeding procedures. Several thousand experimental hives throughout California are being stocked this year with a new hybrid bee, called Hy-Queen, that is being tested for its performance in gathering pollen on such crops as alfalfa.

The ability to associate foraging bees with their parent colonies also provides a powerful tool for detecting colonies that may contain other genetically-carried traits affecting foraging behavior and pollination efficiency. For example, the selection of breeding stock for increasing the pollination efficiency of almonds could take place as follows. Hundreds of bees would be placed near almonds. Thousands of bees foraging on almonds would be tagged and released. Hives containing significantly higher recapture frequencies would be selected for further breeding procedures that would enhance the tendency of bees to forage on almonds. Later, the same stock could be tested on other crops to determine whether the increased efficiency is limited to almonds.

During the past year the magnetic recapture system has been used to trace the flight distribution and range of honeybees on many orchard and field crops. One of the most interesting developments appears to be the inclination of honeybees to forage on a great diversity of plant species, even when productive food sources may be closer than some of the other plants visited. Another observation was that foraging bees seem to respond to various levels of competition from bees originating from other apiaries, and to adjust their foraging territory to minimize competition. For example, when small groups of hives were dispersed within field crops, the effective foraging range frequently was restricted to less than perhaps 200 yards on that particular crop. Yet, the same bees might have flown a half mile or more had they not encountered competition from other nearby apiaries.

These studies suggest that it may be possible to control the foraging range of bees to a greater extent through manipulating inter-apiary competition (by distributing apiaries more strategically). It may also be possible to attain higher degrees of isolation for various seed crops that should be grown in relatively concentrated areas, where soil and weather characteristics are favorable. It is not always convenient or economical to space these fields far apart to prevent undesirable cross-pollination between varieties in different fields.

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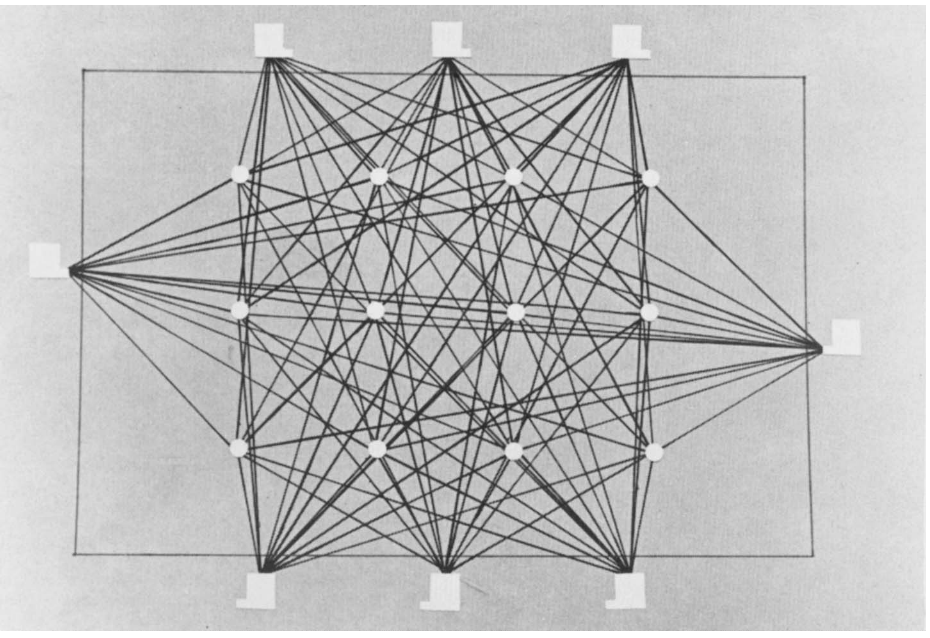
Possible flight patterns of honeybees from eight apiaries to 12 sample points within a "target" crop. Multiple sample points reflect interapiary competition by revealing the comparative visitation frequency at the sample points.



N. C. WELCH • W. H. HART
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LETTUCE CROPS in the central coastal district of California may follow each other in rapid succession on the same land with only a short period between the harvest of one crop and planting of another. Some growers in this area use soil fumigation after a series of 5 to 6 lettuce crops to improve yields and quality. The effectiveness of such fumigation has been attributed to such factors as nutrient release and the control of unidentified pathogens but specific data has been lacking.

During the past four years, preplant soil fumigation trials were conducted in fields infested with stunt nematode, *Tylenchorhynchus brevidens*, and with spiral nematode, *Rotylenchus robustus*, and in one field containing no significant nematode pathogens. In two experiments fumigants were injected by tractor-drawn equipment in a solid (overall) treatment with chisel shanks 12 inches apart set to deliver the chemical 8 inches deep in the soil. In two other experiments the fumigants were injected 6 inches deep and 12 inches apart by handgun in raised beds. Application rates were based on the actual area treated. All harvesting was done by commercial picking crews.

First experiment

The first experiment in 1967 for control of stunt nematode was made in alluvial soil of the Pajaro Valley where a nematode population of about 100 per 100 ml of soil was found. Plot size was 18 × 100 ft, and fumigants were applied in an overall treatment using tractor-