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Field Domiciles and Incubators for the Leafcutting Bee—Their Form and Function in Management

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The alfalfa leafcutting bee, *Megachile rotundata* (Fabr.), was first reported as an efficient alfalfa pollinator in 1959, and because of its highly gregarious behavior was considered amenable to management (Stephen and Torchio, 1961). Initially, managed populations increased rapidly, with annual increases of two to three times where a suitable nesting medium was provided and an excess of alfalfa bloom was available. Within a few years, various producers had built up enormous local populations for alfalfa pollination. By the mid 1960s, the large, densely aggregated populations became hosts for a series of parasites and nest destroyers, such as *Trogoderma*, *Tribolium*, *Monodotomerus*, and *Tetrastichus*, and by the late 1960s, many producers found it difficult to maintain bee populations at their earlier levels.

The increase in pest problems prompted some growers to adopt prophylactic practices to minimize losses, but prophylaxis was neither regiously practiced nor ridgidly followed on a seasonal basis.

An additional factor in the decline in the annual rate of increase of the leafcutting bee is the locally high incidence of unconsumed pollen masses—generally referred to as "unexplained mortality." A cell is constructed and provisioned by the bee and an egg is laid on the surface of the pollen. However, rather than developing, either the egg or young larva dies. Over the years, this mortality has been attributed to a variety of causes including population inbreeding (Eves and Johansen, 1973), pesticide residue (Waller, 1969), or saponin content of alfalfa leaves (Thorp and Briggs, 1972). None proved to be of great significance.

It has been shown that both eggs and young larvae are very susceptible to short exposures at high temperatures (Undurraga, 1975). Recent laboratory studies have indicated that all immature stages of the bee from eggs through pupae are killed by as little as a 15-minute exposure to in-cell temperatures of 50° C (122° F) (Undurraga and Stephen, unpublished data). Temperatures within cells located in both straws and boards have been monitored, and in nesting material directly exposed to the sun, or given inadequate protection, temperatures of more than 120° F for periods of more than an hour are not uncommon. In fact, temperatures of more than 60° C (140° F) have been recorded from cells in nesting media facing the early morning sun. Even in late afternoon, bottom cells in boards backed against a ⅜-inch plywood domicile wall have registered temperatures in excess of 50° C (122° F). Thus, it is essential that field domiciles provide protection from the sun to minimize heat-associated mortality.

In the last three years, chalk board disease has become the major limiting factor in propagation of the leafcutting bee, with losses from the disease exceeding 60 percent in some localities (Stephen and Undurraga, 1978). The etiology of the disease is poorly known and, thus far, prophylactic measures have been the only effective means of limiting the disease. The structure of the domicile plays a major role in bee management, providing protection from the excessive heat and high humidity, both apparently directly influencing the incidence of chalk brood. A key to disease control is the loose cell system of bee management (Stephen and Undurraga, 1978), and the type of field domicile utilized has a direct bearing on the practicality of an overall seasonal management program.

The field domicile and its construction should be a major consideration for each producer in developing a management scheme. The domicile must be integrated into a phase-out program for diseased or parasitized materials, be accessible to bee emergents from an incubator in which the cells are placed, and provide nesting media with adequate protection from the sun, rain, and/or excess humidity.

Size of Domicile

Shortly after the leafcutting bee was domesticated, it was recommended that small domiciles be constructed (10 to 40,000 holes) and that these be located in and around the fields to be pollinated (Stephen, 1962). This recommendation was based on the observed preference of the bee to work alfalfa in close proximity to the domicile, and the then prevalent idea that females would not forage more than a few hundred feet from their nesting site. Females usually forage on the closest available bloom, but it is now known that they will travel more than one-fourth mile from the domicile without abandoning the site. The distance they forage, without becoming lost or drifting, appears to be directly related to the domicile size. That is, distinctively painted large domiciles serve as markers on which the bees can readily orient. Small field domiciles, scattered through the field, are poor orientation markers and cause confusion among foraging

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females. Further, where many small domiciles exist in a limited area there is a tendency for nesting females to abandon those least populated and drift to those with stronger nesting populations. The females are attracted to those sites in which the aggregating pheromone released by nesting females is strongest.

Thus, field domiciles should be sufficiently large and distinctively marked to act as good orientation sites for foraging bees. Each nesting population should be large enough to maintain the integrity of that site (minimum of 20,000 nesting females in 60 to 80,000 nesting holes). Large domiciles (200 to 800,000 nesting holes with 50 to 200,000 females) should be mobile to permit moving them within the field or from one field to another. As a rule of thumb, there should be three to four available nesting tunnels for every nesting female. At this ratio, the females will be distributed evenly in the nesting media within a domicile, and this density of bees will assist in providing control of certain parasites, especially *Sapyga* (Undurraga and Stephen, in manuscript).

Domicile size and structure will determine the extent of air circulation and ventilation that will occur around the nesting material. Good air circulation with air interchange is vital to keep in-domicile temperatures at or below those of the ambient air. High temperatures (100° F-plus) not only contribute to egg and larval mortality but are believed to stress developing larvae and thus foster the development of chalk brood. There is evidence that chalk brood also is more prevalent where humidity is high, a condition that is minimized with good air interchange.

Our tests have shown that in domiciles with an interior height and depth of approximately 8 feet, and a chamber size of 6 X 8 feet (Figures 1a, 1b), temperatures will be maintained from 9 to 14° F cooler than ambient temperature. The difference between domicile and ambient temperature is greater in hotter weather, averaging 11° when the ambient temperature is more than 100° F.

Basic Elements of a Domicile

A domicile design, regardless of its size or mobility, should incorporate the following basic features:

1. *Protection of the nesting media from the direct sun.* This is best accomplished in domiciles with 12- to 18-inch roof overhang on all sides; sufficient depth to the domicile so the nesting media can be protected from sun, rain, and wind; an awning to provide shade (Figure 1a); and by facing the domicile to the south or southeast.

2. *Optimal ventilation to minimize in-domicile temperature and humidity.* As mentioned above, larger domiciles have better air circulation and are more readily ventilated. In addi-

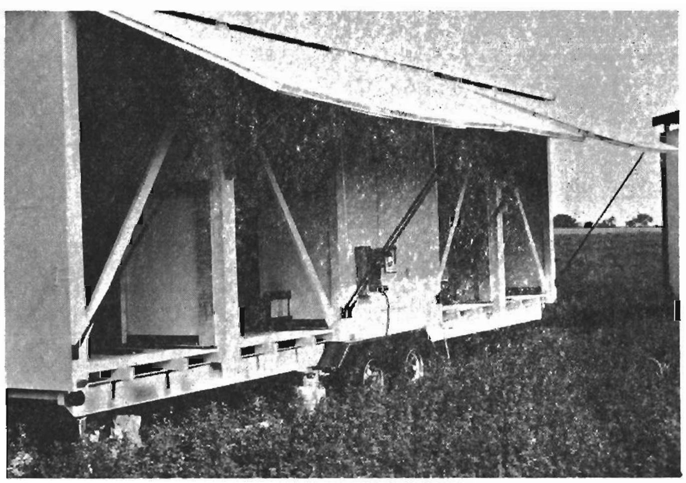

Fig. 1a. Field domicile with incubator located medially and with 4 nesting chambers approximately 6 x 8 feet.

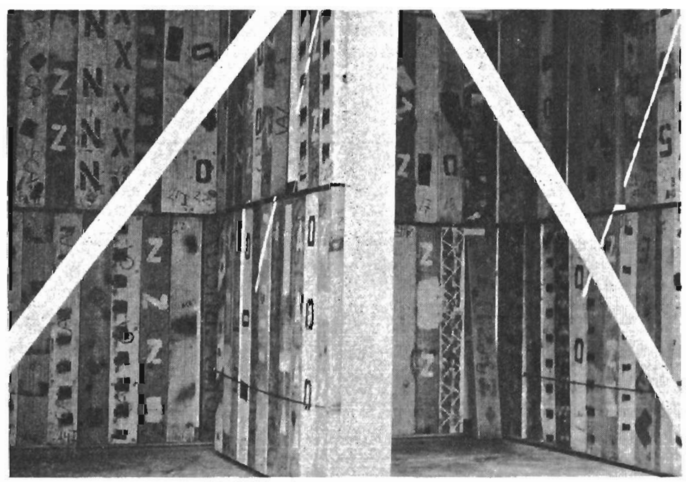

Fig. 1b. Chambers of above domicile fitted with boards for bee nesting.

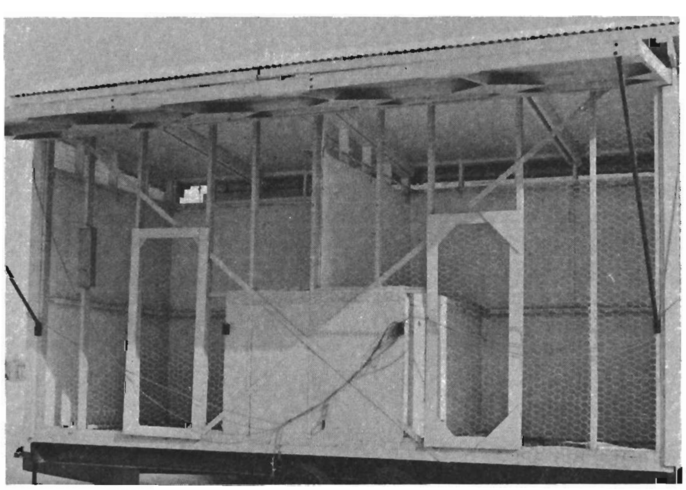

Fig. 1c. Field domicile with incubator located in lower middle section and with 2 nesting chambers approximately 8 x 10 feet.

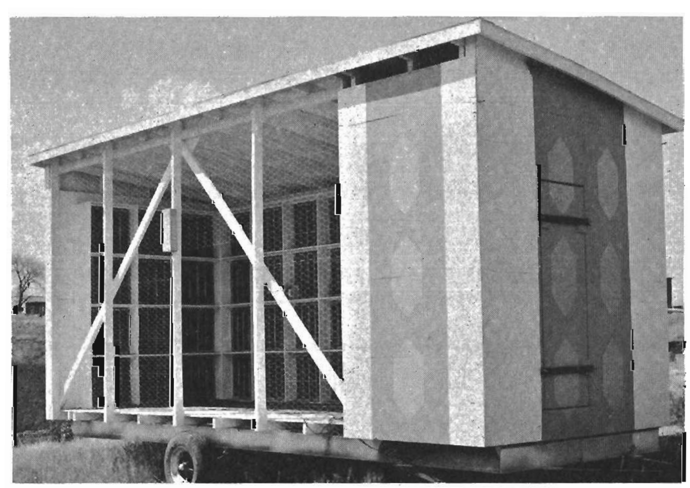

Fig. 1d. Field domicile with incubator located at one end and with a single, large nesting chamber approximately 8 x 16 feet.

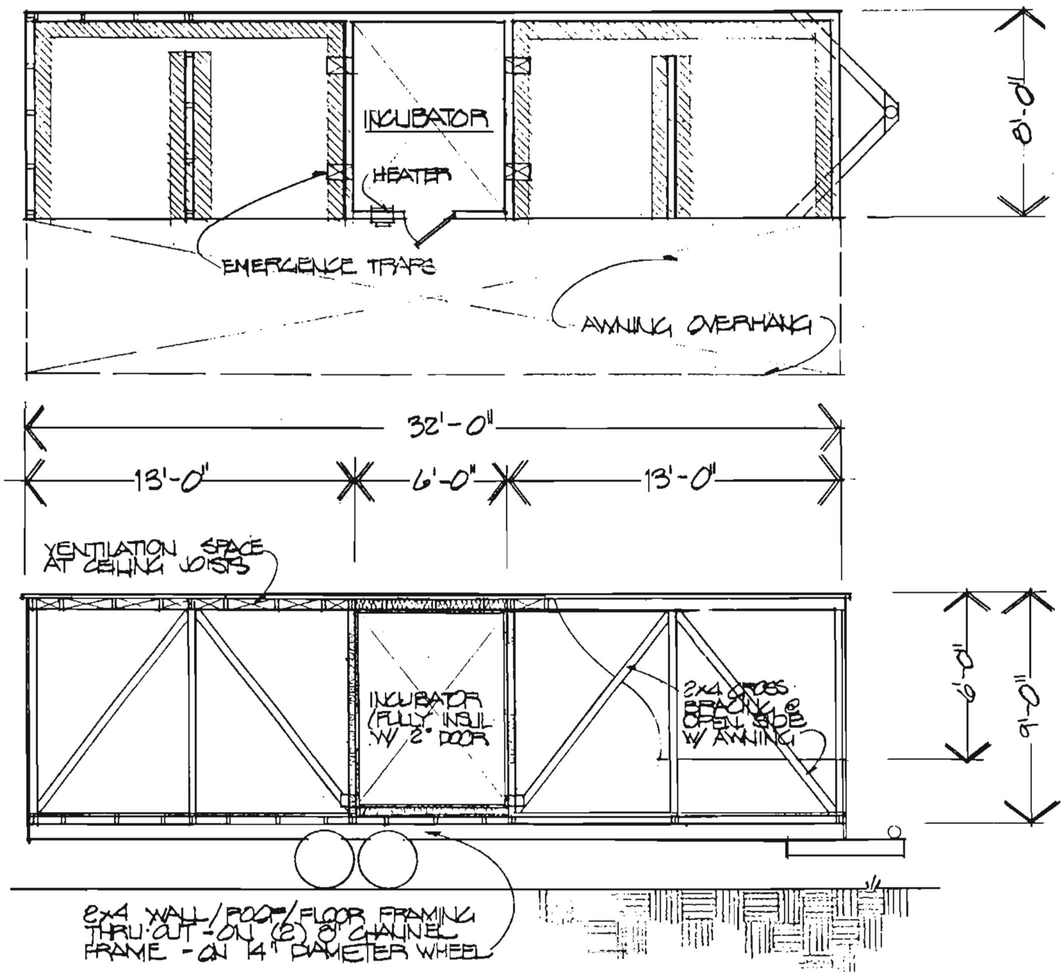

Fig. 2a. Structural details of field domicile with medially located incubator.

tion, there should be an open air space of 4 to 8 inches between the top of the nesting medium and the domicile roof to promote air circulation. This air space must be screened with 2-inch chicken wire mesh to prevent the entry of birds. A floor in the domicile, elevated about 2 feet above the ground, is desirable because it will help reduce humidity originating in plant growth beneath the domicile, reduce day-night temperature extremes in the domicile, and permit cleaning and decontamination of chalk brood spores. Where intervening walls are used to accommodate additional nesting media in large domiciles, these walls should extend only to within a foot of the rear of the domicile so as not to impede air circulation or movement of bees (Figures 2a, b).

3. *Double-walled construction.* The domiciles diagrammed in Figures 2a, b have 2- X 4-inch studs and rafters, with inner and outer walls of ⅜-inch plywood, or with inner

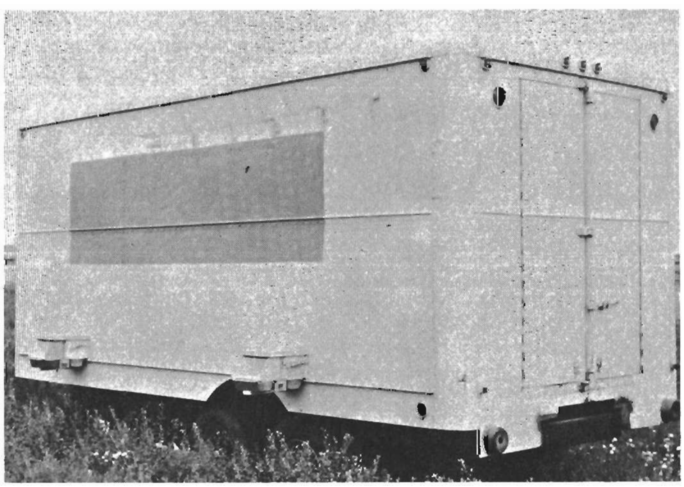

Fig. 3a. Self-contained mobile incubator with emergence traps afixed to one side.

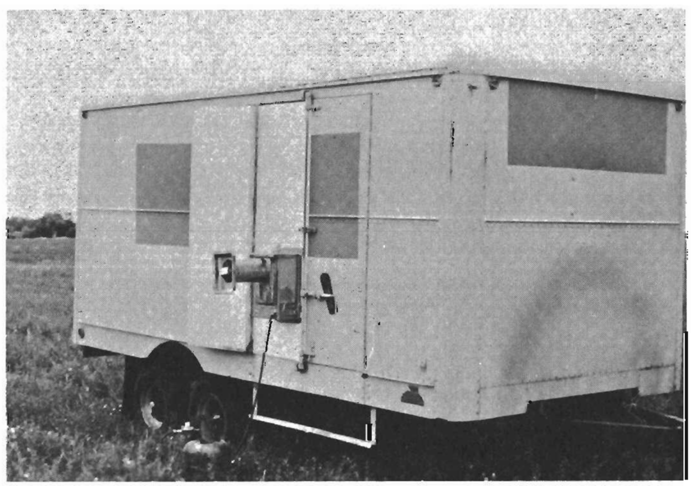

Fig. 3b. Self-contained mobile incubator with an outside-venting gas heater.

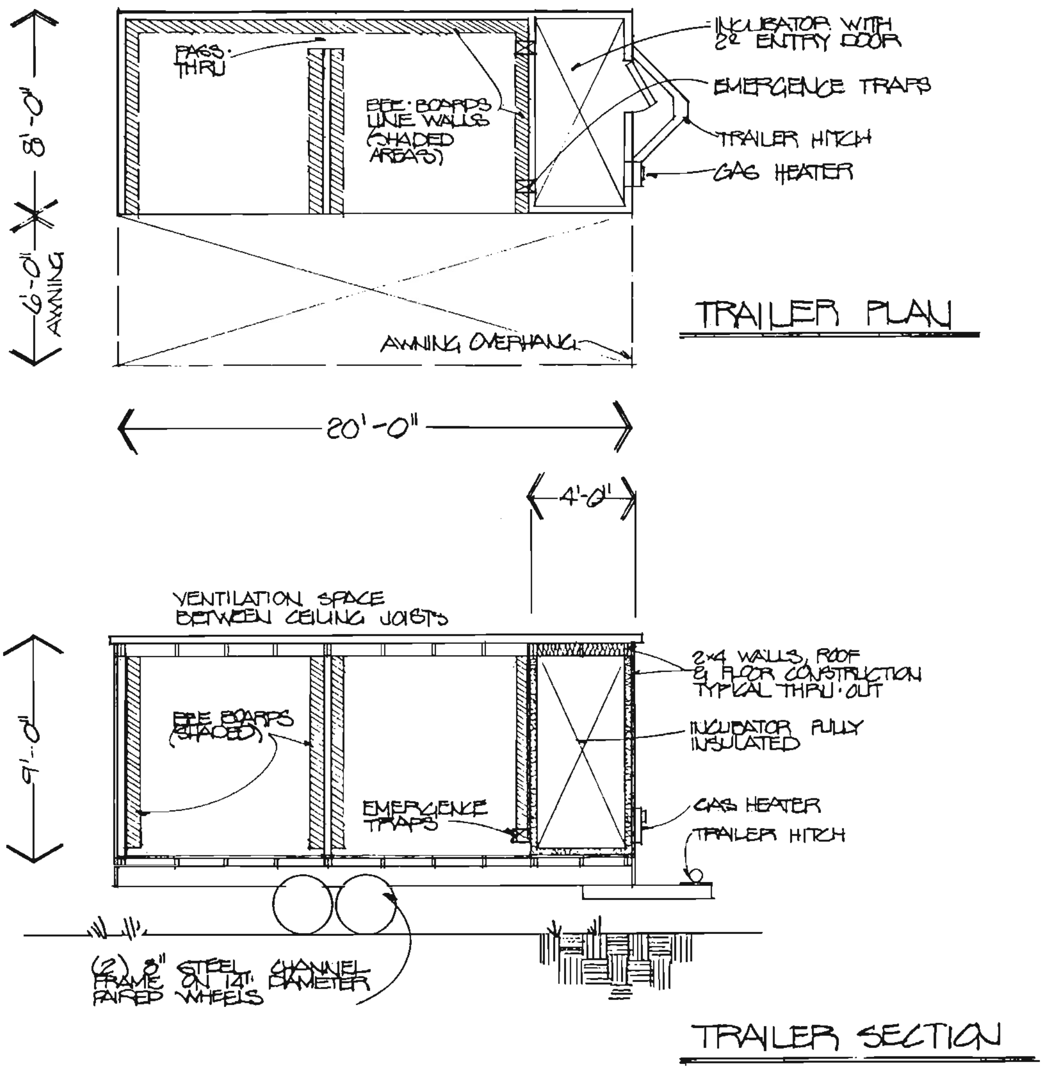

Fig. 2b. Structural details of field domicile with incubator at one end.

plywood and outer steel sheeting to form a double wall. Lethal temperatures (more than 49° C or 120° F) may be reached in the bottom series of cells in either boards or straws when the nesting medium is flush against the inside wall of a domicile covered with a single sheet of plywood. Such temperature extremes are prevalent especially in nesting materials located along walls struck directly by the afternoon sun. Tests using uninsulated double walls of ⅜-inch plywood and double walls with insulation indicate the double walls with an air space are as effective as the insulated wall in reducing temperatures to non-hazardous levels.

4. *Mobility*. Large domiciles with 150,000 or more nesting females (30 to 500,000 nesting tunnels) can pollinate effectively 25 or more acres of alfalfa in a month, or 15 acres in 10 to 14 days. Such domiciles must be mobile so they can be moved at night to a new foraging site, otherwise the bees may starve or abandon the domicile.

5. *Incubation*. The incubation of overwintered prepupae has been recommended as a means of synchronizing bee emergence with the bloom of alfalfa to be pollinated. During incubation, many parasites and nest depredators can be removed by trapping. Incubation at 82° to 86° F (28° to 30° C) is vital to a loose-cell management system to minimize mortality during emergence, but it is equally beneficial in the management of cells in solid nesting materials. In the past, cells have been incubated at a central site until male emergence began. Then the trays containing the cells were transferred to a field domicile. The need to protect the cells from the lethal effects of the direct sun required that the trays be placed in a well-shaded portion of the field domicile. If a series of cool days and/or nights followed their transfer to the field, the cells became chilled and a prolonged period of high temperatures was necessary to raise the cell temperatures above the 70° F (21° C) required for development and emergence. We believe these cold periods to be responsible for the high loose-cell mortalities (20 to 40 percent) which some producers have reported. Samples of cells taken from trays during incubation and transferred to the laboratory consistently had 95 to 98 percent emergence, which supports our contention. Thus, we strongly recommend that a field management system be utilized in which emerging bees are held at or near a constant 86° F (30° C) until emergence is complete.

Further control can be effected during spring emergence by equipping the incubator with a combination heater-air conditioner. The most common and inexpensive units are electrically operated and are most practical on a self-contained mobile incubator. The unit can serve as the heat source, prior to bee emergence, by locating the incubator near a power source. If it proves necessary or desirable to delay emergence after the incubator has been moved to the field, it can simply be pulled to a power source at night for refrigeration. Weather during the last half of June in the Pacific Northwest is highly unpredictable, and should it turn cold for several consecutive days bees will continue to emerge and die unless the incubator temperature can be adjusted to delay their development. Normally, the incubator cannot be adequately cooled by opening the door at night to air it out because the metabolic heat generated by large numbers of developing larvae and pupae is sufficient to maintain temperatures at or above the threshold for development. With a suitable air conditioner, the interior of the incubator can be kept at 50° to 60° F (10° to 15.5° C), completely arresting development. We have found that development and emergence can be delayed for up to 10 days at any time during the emergence period, with no mortality, when the cells are held at the above temperature. Such control can often prevent drastic bee losses during inclement weather, or be used to delay bee emergence should alfalfa bloom be later than anticipated.

In-Domicile Incubators

Each of the domiciles shown in Figures 1a, c, and d, has an incubator at one end, the middle or lower-middle section, and each is insulated on all sides. The incubator is equipped with a thermostatically controlled outside-venting gas furnace* to maintain the incubating cells at a constant temperature. Care should be taken to purchase a heater with a high-quality thermostat, or the unit should be fitted with a second high-temperature cut-out. On occasions, growers have lost substantial portions of their bees because of thermostat malfunction which permitted the incubator temperature to rise beyond 122° F (50° C). An indoor-outdoor thermometer should be mounted on the incubator so interior temperatures can be quickly read, and the incubator should be monitored several times a day. We have found that the heater in a well-insulated incubator in the field can be turned on in the early morning, monitored for a few hours, and then turned off (or to "pilot") at noon. This usually warms the incubator sufficiently to promote good (but not maximal) daily bee emergence. Each incubator has from one to four emergence traps located so the bees emerge directly into the domicile in which the nesting media are housed.

Self-Contained Incubator

The size of a self-contained mobile incubator should be based on the number of bees (or bee boards) the producer has, and the number of field domiciles he expects to populate in a fixed period during late spring. The incubator shown in Figure 3a is 16 X 8 X 6 feet and can accommodate approximately five million loose cells or 650 boards. Each incubator can be equipped with an electric heater-air conditioner to maintain optimal interior temperatures. Further, as mentioned earlier, its mobility permits returning it to a power source for cooling should inclement weather call for delaying bee emergence. Once in the field, a secondary heat source must be utilized to achieve rapid and continuous emergence. This can be effected through the use of a thermostatically controlled outside-venting gas furnace fitted directly into the incubator body, or on a removable door as illustrated in Figure 3b. The heater should be carefully monitored.

* (An outside-venting gas heater must be used. Non-vented gas heaters consume free oxygen in the incubator and cause the death of developing larvae.)

Phase-out or *Sapyga* traps must be added to the incubator. Two traps covering incubator openings of 5 X 8 inches each are adequate for the size of the incubator in Figure 3a.

The interior of the incubator must be thoroughly sealed so only light entering through the emergence traps will attract the emergent bees to the exit. Competing light leaks will result in the loss of adults unable to find their way out. Painting the interior floor white enhances the limited light entering through the emergence traps and painted surfaces are also more readily sanitized for disease control (Stephen and Undurraga, 1978). Racks to accommodate trays of loose cells or boards should be designed for each incubator and these should be made interchangeable. Care should be exercised in the placement of the trays and/or boards, allowing adequate space between the top of the trays and/or the face of the boards so sufficient light will be visible to emerging bees and allow them to move toward the traps.

A 6- to 8-inch clearance must be maintained between the floor of the incubator and the bottom of the rack so emerging bees fall directly into an open arena from which light of the emergence traps can be seen.

The mobile self-contained incubator may be kept at a single field site and the domiciles to be populated moved next to it, or the incubator can be pulled adjacent to a field-positioned domicile and moved after that domicile is adequately populated. If the incubated bees are heavily infected with chalk brood, it is recommended that the incubator be kept at one position and the domiciles placed nearby. This will help to confine much of the disease spore inoculum carried by emerging adults to the area about the incubator rather than distributing it from field to field.

In the latter scheme, it is essential that the population in the domicile located adjacent to the incubator be built up rapidly and the domicile moved to the field before the females become oriented to the emergence site. Normally, newly emergent females require three to five days to become fully oriented to the nesting domicile. Only one, or at most two, domiciles should be made available for emergent bees at any time. Maintaining constant optimal temperatures in the incubator results in an accelerated emergence, and a large domicile (700 to 900,000 holes) can be populated adequately in three days. Once populated, the domicile can be moved and replaced with a second to accommodate the emergent bees of the following day. A large field domicile, well marked and distinctively painted, is a major land mark itself and helps prevent drift after it has been moved.

Qualifications

Domiciles, incubators, and management schemes must be developed for each zone in which the leafcutting bee is propagated. In the Pacific Northwest alone, seed alfalfa is produced in distinctly different climatic areas: some rarely if ever have frost after June 1, and experience periods of intense summer heat; others can expect frost at any time of the year and have summer temperatures which rarely exceed 90° F (32° C).

Outside the PNW, the leafcutting bee is propagated in such climatically diverse areas as the Sacramento Valley of California to the northern portions of Saskatchewan and Alberta in Canada. It is readily apparent that a field domicile designed to protect the nesting population of bees from the intense heat of California (or some areas of the PNW) is functionally inappropriate in northern Canada, where in-domicile temperatures must be enhanced to achieve maximal bee activity during the relatively short flight period. Thus, where morning temperatures are low and bees do not begin foraging until 10 a.m. to noon, an awning should not be used and the roof may be replaced with corrugated fiberglass or a comparable material to warm the interior by radiation. Yet, all domiciles should be situated to avoid the rays of the morning sun directly into the nesting tunnels, should provide protection from wind and rain, and should be well ventilated to keep in-domicile humidity low. In general, the bee domicile should be designed so as to minimize temperature extremes to which bees and developing larvae are exposed, i.e. 15° to 32° C (60° to 90° F).

Further, the type and size of the domicile also must be a function of the purpose for which the leafcutting bee population is being propagated. The domiciles illustrated in this bulletin are designed to accommodate large, densely aggregated populations of the bee for alfalfa pollination. These populations are meant to achieve rapid pollination of a limited crop acreage, and because of their large numbers, bees may compete for both nesting space and available bloom. This competition may result in a reduced rate of increase in any generation of the bee. Domiciles intended to accommodate a leafcutting bee population for expansion only should be small, fixed in position to avoid orientation problems, and located where forage is superabundant.

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