HEAT RELEASE FROM ALFALFA LEAF-CUTTER BEES

T.L. Lambden
Agricultural Engineering Department
University of Saskatchewan
Saskatoon, Saskatchewan

W.J.D. Shaw
Mechanical Engineering Department
University of Saskatchewan
Saskatoon, Saskatchewan

G.H. Green
Mechanical Engineering Department
University of Saskatchewan
Saskatoon, Saskatchewan

INTRODUCTION

The recent increase in domestic and export markets for alfalfa seed grown in Western Canada has resulted in an increased demand for the alfalfa leaf-cutter bee (*Megachile rotundata* F.). This bee has been domesticated and is an effective pollinator of the alfalfa plant. Because this bee cannot survive naturally over winter in Canada, the larvae in their leaf-cutting cells must be stored indoors to break diapause and must be incubated for rapid uniform emergence in the spring. Overwintering requires a dry location with a temperature of approximately 4.44°C. During incubation the chamber should be maintained at about 29.4°C and 70% RH. It is during the period of incubation and postincubation storage that the temperature and humidity are critical to the health of the bees. When the temperature is lowered the incubation process is prolonged, and at higher temperatures (32.2°C or more) development can be hindered and death of the bees can result (2). As the bees cost approximately 0.5 cent each, or $2000.00 for a 405-m^2 (100-acre) field, overheating in an incubator can be expensive.

The larvae cells are incubated in trays 5 cm deep with a layer of cells about four deep (a tray can hold several thousand bees). These trays usually have plywood bottoms and screen tops and are stacked in the incubator. Tray temperatures must be maintained near 29.4°C. This can be accomplished by ventilating the incubator to remove excess heat produced by the bees. To design a ventilation system, heat production of the bees must be known. It was for this reason that an investigation was conducted into the metabolic heat rate of the bees and its effect on the heating and cooling requirements of the incubation chamber.

To measure the quantity of heat released by a sample of 2,000-3,000 bees, a calorimeter was built in which the bees could be placed during and after incubation.

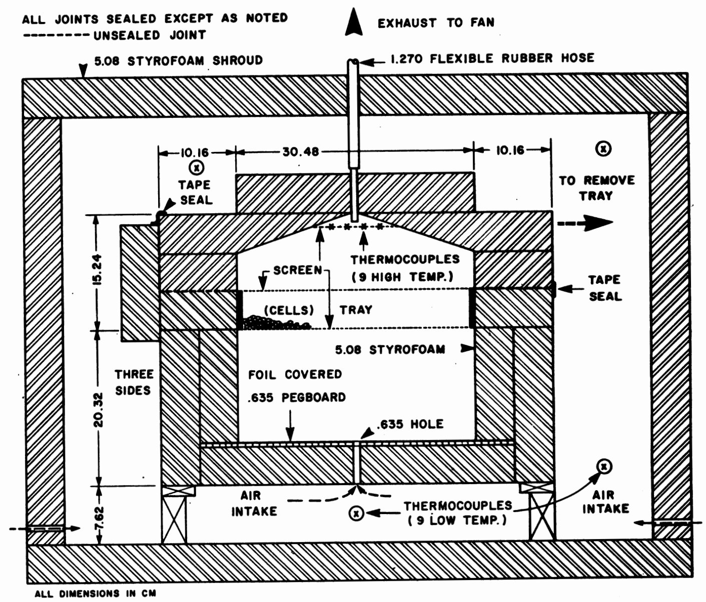

Figure 1. Bee calorimeter and shroud.

CALORIMETER CONSTRUCTION AND OPERATION

Estimates of the heat released by the bees and the measurement range required were obtained from Church[a] as given in Table I. These values were based on published figures (1) for oxygen consumption in insects.

The method employed to measure the heat released was to use a 10-cm centrifugal fan to draw air through the calorimeter (Figure 1) and measure the change in air temperature using a copper-constantan differential thermopile. The unit was placed in a controlled atmospheric chamber maintained at 29.4°C and 70% RH. A polystyrene shroud was placed around the calorimeter to dampen the small changes in temperature that occurred in the chamber.

TABLE I APPROXIMATIONS OF MAXIMUM HEAT RELEASE BY ALFALFA LEAF-CUTTER BEES AT 30°C

Stage	One bee
In flight (g cal/h)	6.0
At rest (g cal/h)	0.60
Pupa-prepupa (g cal/h)	0.150

The size of the thermopile required was determined by assuming an air temperature change of 2.78 C degrees. To obtain this change, the airflow through the calorimeter was restricted by reducing the inlet to a .635-cm hole. The air entered at the bottom of the calorimeter, passed upwards through the tray of bees, and exited at the top of the calorimeter. A thermopile using nine thermocouples was used and its output was measured with a millivolt potentiometer. Air discharging from the fan passed through a 5-cm air exhaust pipe that contained straightening vanes and was of sufficient length of obtain uniform velocity airflow through a

[a] Personal communication from Dr. N.S. Church, Research Station, Agriculture Canada, Saskatoon, Saskatchewan.

RECEIVED FOR PUBLICATION AUGUST 3, 1972

0.9525-cm diam nozzle placed in the end. A manometer connected across the nozzle indicated that the measured airflow was 0.0586 m^3/min.

Given the change in temperature and the flow rate of the air the amount of heat released could be calculated.

TEST PROCEDURE

Preliminary calibration tests were run with an electric heating element placed in the calorimeter. A range of millivolt readings were obtained using inputs from 0.5 to 3 W. The corresponding heat balances were checked.

The overwintered bee cell samples were obtained from local sources, placed in the test tray, and incubated for 18-21 d. When approximately 70% of bees had emerged the tray was placed in the calorimeter, the calorimeter resealed, and placed in the controlled chamber at 29.4°C and 70% RH. A preliminary test using a sample of bees showed that there was a variation in heat release with respect to time that was not anticipated. For the remaining tests the bees were fed by placing honey on the top screen of the tray prior to being placed in the calorimeter. Millivolt readings were then taken every hour for the first 6 h and every 2 h for the next 6 h and at intervals not exceeding 10 h for the next 24 h for a total period of 36 h. The calorimeter was opened and the bees were fed again prior to the next test. Following all tests the bees were killed and the mixture of dead bees, nonemerged cells, and empty cells were left in the trays. An electric heating element was then arranged among this mixture to simulate the heat release from the bees. Calibration was then conducted with the heat now being generated electrically at the same location as it was by the live bees. Due to radiation and airflow variations a difference between the preliminary calibration with empty tray and the final calibration with heating element in the bee tray with dead bees resulted in a maximum difference of 9%. The calibration curve for the heating element in the bee tray was fitted with a correlation coefficient of 0.9881 to the equation.

$$Q = (mv + 0.003)\ 3.412 \qquad (1)$$

where

Q = heat released, kg cal/h
mv = thermopile output, millivolts.

Following final calibration, the number of undeveloped cells were counted to determine the number of emerged bees.

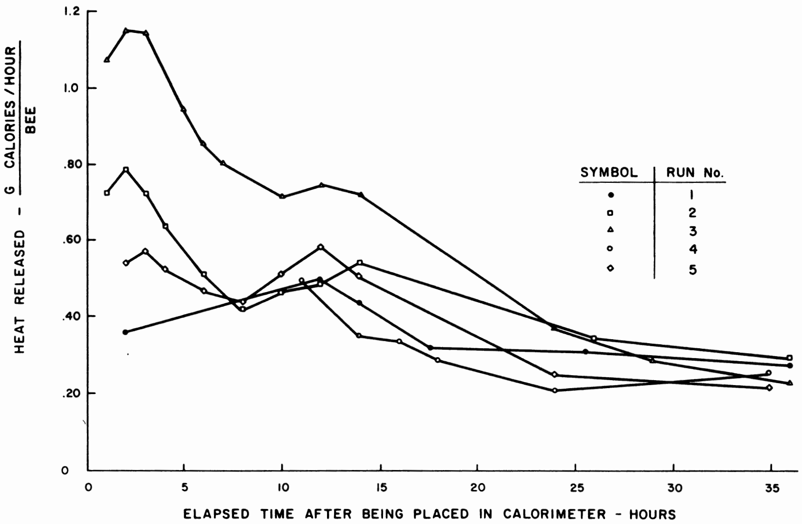

Figure 2. Heat release from emerging and emerged alfalfa leaf-cutter bees vs. elapsed time in calorimeter.

RESULTS

Tables II and III summarize the data obtained. Table II indicates that the percent emergence under these test conditions ranged between 81 and 89%, which correspond to typical field values. The variation of heat release with respect to time is shown in Figure 2. The calorimeter required approximately 8 h to stabilize after being placed in the controlled chamber. The relatively high values occurring up to 5 h are probably due to increased activity of the bees due to feeding and presence of light prior to the start of the test. At approximately 12 h, an increase in heat released occurred, possibly due to increased activity resulting from a diurnal cycle of activity in the bees, which were in the dark when in the calorimeter. Heat release values then generally decreased for the next 24 h to an average value of 0.2575 g cal/h per bee at 36 h.

A test to determine the latent heat release of the bees showed there was no measurable release of moisture at this activity level. Known data (1) on moisture release by insects substantiates this.

TABLE II BEE SAMPLE SIZE AND EMERGENCE

Sample	No. cells	No. bees emerged	% emergence
A	2370	1917	81.0
B	3264	2864	89.0
C	2438	2014	82.0

TABLE III BEE HEAT RELEASE IN CALORIMETER AFTER SPECIFIC TIMES

	12-h heat release	24-h heat release	36-h heat release
Avg g cal/h per bee	0.5599	0.2983	0.2575
SD	0.1126	0.0695	0.0314

ALFALFA LEAF-CUTTER BEE INCUBATION CHAMBERS

The lowest value in heat release, 0.2575 g cal/h per bee would occur only when the chamber was dark and when there had been no disturbance of the bees. For design, a value of 0.56 g cal/h per bee is suggested, that is, a value of 560 kg cal/h per million bees.

The bees are usually placed in the incubation chamber around June, and they emerge 18-20 d later. For western Canada there is a 15% chance that the outdoor temperature will be greater than 32.2°C. Therefore, the chamber should be designed for a cooling load required by this temperature, and the appropriate amount of solar radiation if located outdoors, and a heat release of 560 kg cal/h per million bees.

There must be adequate spacing between trays of bees so that a free even flow of air can take place over every tray. Free air space between trays should not be less than 10 cm. The incubation chamber should be well sealed with a vapor barrier so that it is possible to maintain 70% RH in the space. The environment should be controlled within ±1.11 C degrees and ±5% RH to obtain the shortest possible incubation period.

If it is intended to store the bee cells in the winter at 4.44°C in the same chamber that is used for incubation at 29.4°C and 70% RH, it is necessary to select the heating and cooling ventilation coil with a low temperature difference (i.e., large area) so that a high humidity can be maintained during incubation. If direct expansion refrigeration is used in the cooling coil, then a back pressure regulator should be installed so that the appropriate coil pressure can be maintained. This will have a range to suit the 4.44°C temperature required in the winter season and the 29.4°C required in the incubation period

CONCLUSIONS

The sensible heat release of the alfalfa leaf-cutter bee during and after emergence in incubation chambers ranges from 0.257 to 0.559 g cal/h per bee and it is suggested that the higher value be used in the design of the incubation chambers. The value reported agrees well with estimates made from data reported for other insects of comparable characteristics. Latent heat output is negligible. The heat release from the bees is a significant part of the cooling load, and the incubation trays must have spacing that allows free flow of air to remove the heat released by the bees. Adequate attention must be paid to coil selection and control in incubation chamber design so that high humidities can be maintained in the space.

SUMMARY

The alfalfa leaf-cutter bee is used as a pollinator of alfalfa. It cannot survive naturally in the northern United States and Canada, so it is stored in its cells at 4.44 degrees Celsius during the winter and incubated for emergence in the spring. Incubation should be done at a temperature of about 29.4 degrees Celsius and a relative humidity of 70 percent. If the temperature exceeds 32.2 degrees Celsius a high mortality of bees will result. To calculate the cooling load of the incubation chamber the percent emergence of bees and the heat released by the developing bees must be known. A calorimeter was designed, and values of heat released from small lots of bees were determined. Suggestions for the design of the incubation chamber are made.

ACKNOWLEDGMENTS

The work of the class Mechanical Engineering 420, H. McMahon, and Dr. N.S. Church at the Research Station, Agriculture Canada, Saskatoon, Saskatchewan, and G.A. Hobbs at the Research Station, Agriculture Canada, Lethbridge, Alberta, is gratefully acknowledged.

REFERENCES

1. Church, N.S. 1960. Heat loss and the body temperatures of flying insects. I. Heat loss by evaporation of water from the body. J. Exp. Biol. 37: 171-185.

2. Hobbs, G.A. 1967. Domestication of alfalfa leaf-cutter bees. Can. Dep. Agr. Publ. 1313. Information Canada, Ottawa, Ontario.