THERMAL MORTALITY STUDY ON THE BOLLWORM,

HELIOTHIS ZEA (BODDIE)

By

WILLIAM BRUCE MASSEY JR.

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Thesis Approved:

Jerry H. Young

R. G. Price

R. D. Eikenbary

D. Durham
Dean of the Graduate College

764173

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INTRODUCTION

THERMAL MORTALITY STUDY ON THE BOLLWORM, *Heliothis zea* (Boddie)

A number of studies have been conducted to determine the thermal death point of different species of insects. Dean (1913) determined that heat could be used for control of mill insects that were inaccessible to gas or the vapor of any fumigating material. He found that no mill insects could withstand, for any length of time, a temperature of 48.2 C to 50 C. He demonstrated in these tests that heat was the most practical, convenient, efficient, and inexpensive method of controlling mill insects.

Bacot (1914) determined the influence of temperature on the survival of eggs and larvae of *Cimex lectularius* (L.). In his tests, 20 unfed *C. lectularius* kept at a temperature of 45 C did not survive after 15 hours exposure.

Cressman (1933) conducted a test in the library of the United States Circuit Court of Appeals in the Post Office Building, New Orleans, Louisiana, using heat to control the cigarette beetle, *Lasioderma serricorne* (Fab.). The cigarette beetle had infested the leather bindings of books in all parts of the library. The temperature used in the test was 60-63 C, which was maintained for 6 hours. An inspection of the premises at 3 and 37 day intervals revealed no evidence of the insect in any stage of development.

Baker (1956) reported the eradication of DDT resistant C. lectularius (L.) from a 11 story apartment house in Alaska. Electric heaters were used to raise the temperature to 150-160 F for 6-8 hours. No bugs were found alive after the treatment.

A good bibliography of studies on heat mortality of household and stored-grain pests is given by Sterling (1964).

The majority of studies done on heat mortality of insects has dealt with household pests or stored-grain pests. One exception is Guthrie and Decker's (1954) work on the chinch bug, Blissus leucopterus (Say).

Recent interest in the possibilities of nonchemical or integrated control of insects, brought about by problems arising from the use of chemical pesticides, has resulted in increased research to find nonchemical controls of pests. Batchelder and Porterfield (1965) used a self propelled thermal application unit to defoliate cotton in the field. Kent (1966), using a laboratory model of the thermal application unit (Figures 1 and 2), reported in greater detail the operation of the defoliating unit.

While observing their field operations it was noted that several species of insects were killed by the heat emitted from the thermal defoliating unit. From these observations it was thought heat might be a nonchemical means of controlling insects in cotton.

The purpose of this study was to determine in the laboratory what range of temperatures and time exposures would be fatal to the bollworm, Heliothis zea (Boddie).

This investigation was conducted during August, September, and October of 1969 and May of 1970.

METHODS AND MATERIALS

Progeny of moths collected in light traps at Stillwater, Oklahoma, September, 1966 and reared in the laboratory for 17 generations, and moths collected in the field at Stillwater, Oklahoma, July, 1969, were used in the tests. Some of the F_1 larvae were used in the test and the remaining were used to maintain the colony and produce other test larvae. Tests were conducted when the larvae reached the third instar.

LARVAL REARING

The rearing procedures followed were similar to those described by Adams (1966). Some modifications were made to his procedures to facilitate the raising of a larger number of larvae.

Approximately 12 pairs of moths were placed in oviposition cages made from one-gallon ice cream cartons and lined with paper towel. The cage tops were covered with nylon tulle to provide ventilation and also an oviposition surface. A 1-dram vial was filled with an 8% honey solution and provided with a cotton ball wick. This vial was inserted into the side of the carton to provide food for the moths.

Eggs were deposited on the tulle, cotton plugs, and toweling on the sides of the cartons. When the eggs reached the dark ring stage the tulle, toweling, and cotton plugs were placed in a one-half-gallon ice cream carton and covered with saran wrap. The saran wrap helped to maintain the humidity in the carton while still being able to view

the eggs and larvae. The saran wrap also effectively retained the larvae within the carton until they could be placed on diet.

After the larvae hatched they were transferred singly to 1-oz transparent plastic jelly cups containing approximately ½-oz of artificial diet developed by Adkisson _et al_. (1960) and modified by Berger (1963). The larvae were transferred from the hatching cartons to the cups containing diet by means of a soft, fine tipped, camel hair brush.

A pressurized dispensing device described by Adams (1966) was used to dispense the diet into the 1-oz cups. The device consisted of an 8-qt pressure cooker fitted with a pressure gauge at the air outlet. A kitchen sink hose with spray assembly was fitted to the lid. A metal funnel was altered by removing the spout and welding a flat base to the bottom. This was placed base down in the cooker. Freshly mixed diet in the liquid state was poured into the funnel. The area around the funnel was filled with hot water to prevent solidification of the diet prior to dispensing. An extension of the kitchen sink hose to near the bottom of the funnel allowed all of the diet to be dispensed.

The cups to be filled were placed on wooden trays (16" X 24"). The cups of diet were stored on these trays in the refrigerator. Upon removal from the refrigerator the cups of diet were allowed to set at room temperature for approximately 30 minutes before the first instar larvae were placed on them.

TESTING PROCEDURES

The laboratory thermal application unit used by Kent (1966) was used to produce the desired temperatures. This unit duplicates heat conditions of the field thermal defoliator described earlier. The oven contained a heating area and a treatment area (Figure 1). Air was forced into the heating chamber through a duct, 12 inches square in cross section, by means of a 12-inch diameter centrifugal fan. The air, in passing through the heating chamber, was heated by four Gotcher burners connected to an L P gas supply. After the air was heated it continued through a duct and into a plenum over the treatment area. The treatment area was open on both ends and the bottom. Air in the treatment area was heated by conduction from the oven walls and also by the flow of heated air through 2-inch wide openings at the base of walls (Figure 2). A four-bar link arrangement was used to raise the treatment cage, containing the larvae, into the oven.

Treatment cages were constructed so as to minimize the restriction of the air movement over the larvae. The side of a ½-pint cylindrical carton was cut away except for three narrow strips which connected the top and bottom of the carton. The openings were covered with nylon tulle. Two cages were used alternately during treatments to minimize the effect of placing the larvae on a preheated surface.

Twenty-five different heat treatments were utilized by making all possible combinations of five different temperatures with five different exposure times. Each time and temperature combination was written on a separate 3 X 5 card and these cards were drawn at random to determine the treatment sequence. Each combination was

replicated four times, but on different days. Each replication consisted of 25 larvae. An average mortality was determined for each treatment.

A thermometer inserted through the oven wall was used to determine the internal temperature of the oven. Oven temperature was adjusted manually by increasing or decreasing the supply of L P gas to the burners.

Larvae were removed from individual cups with soft-touch forceps and placed in groups of five in a tulle cage. The tulle cage was placed on the four-bar link arm and raised into the oven. Exposure time was measured by a stop watch; starting when the cage reached maximum height in the oven and terminating when the cage began its downward movement at the end of desired exposure time. The larvae were then removed from the tulle cage and returned to individual containers. Mortality was determined after 48 hours. Larvae were considered dead if tactile stimulation produced no observable response.

RESULTS AND DISCUSSION

Table I lists the larvae mortality per replicate at each temperature-time exposure combination. Average mortality increased within each temperature gradient through the 20-seconds exposure period treatment; indicating the importance of exposure time within the temperature range used in this test. In all temperature gradients, 88% or more of the larvae were killed when the exposure time was 20 seconds.

The average larval mortality per replicate at each temperature-time exposure combination is presented in Table II. The averages from Table II were plotted on isometric graph paper resulting in a three dimensional surface of larval mortality (Figure 3). The three dimensional surface clearly depicts at what temperatures and time exposures the major increases in mortality occur.

The standard deviations between replicates within each temperature-time exposure combination is presented in Table III. The average standard deviation for all 25 combinations was 0.91.

The data obtained in this study indicates that the optimum laboratory mortality rate (80%) may be reached from two directions. First by operating at 135 or 145 C with an exposure time of approximately 12 seconds, or secondly, by operating at 105 or 115 C for approximately 19 seconds. The desired mortality rate may also be realized by operating between these extremes, utilizing 125 C with an exposure time of 15 seconds.

The application of heat to young cotton for the specific purpose of killing larvae of the Heliothis complex is not pratical. The temperatures and time exposures required to kill the larvae would either kill or severly retard the growth of the young cotton (Kent, 1966). Kent (1966) stated that the optimum operatings temperature for the field unit was 245 C, with an exposure time of 2 seconds. Exposure for 2 seconds at 245 C kills larvae in the field. The application of this temperature occurs at the end of the cotton growing season; therefore, no determination of benefit can be derived for the current growing season. Indications are that there may be a carry over to the succeeding growing season resulting in a reduction in larvae population the season following thermal application.

Caged boll weevils, Anthonomus grandis (Boheman), which were placed in the line of operation of the thermal field unit, were all killed. When the cotton is defoliated the plant usually dies due to the loss of its foliage. This premature killing of the cotton plants eliminates the major feeding and reproduction sites of the boll weevil. The destruction of the weevil's food supply may reduce the number of weevils which reach maturity; thereby, lowering the total number of weevils which can over-winter.

Futher studies should be conducted on the long range effects of the thermal defoliating unit on insect populations. For the results of these studies to be significant the cotton to be defoliated with the thermal unit should be an isolated plot or be a large cotton acreage so that migration would not be a significant factor. At present neither of these conditions have been tested.

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APPENDIX

TABLE I

LARVAE MORTALITY PER REPLICATE AT EACH TEMPERATURE-TIME EXPOSURE COMBINATION

Exposure Time		Temperature Deg. C				
		105	115	125	135	145
5 Sec.	Rep. 1	0	0	1	3	1
	Rep. 2	0	1	2	0	1
	Rep. 3	1	0	1	0	1
	Rep. 4	0	1	2	1	1
10 Sec.	Rep. 1	0	1	2	19	17
	Rep. 2	0	1	1	11	16
	Rep. 3	0	1	1	18	14
	Rep. 4	1	1	2	16	15
15 Sec.	Rep. 1	3	19	19	25	24
	Rep. 2	4	17	19	24	25
	Rep. 3	10	16	20	25	25
	Rep. 4	5	16	20	24	25
20 Sec.	Rep. 1	22	23	24	23	25
	Rep. 2	22	19	24	25	25
	Rep. 3	21	18	25	25	24
	Rep. 4	23	20	25	24	25
25 Sec.	Rep. 1	24	25	25	25	25
	Rep. 2	21	25	24	24	24
	Rep. 3	21	25	24	25	25
	Rep. 4	23	25	24	25	25

TABLE II

AVERAGE LARVAL MORTALITY PER REPLICATE OF EACH HEAT TREATMENT-TIME EXPOSURE COMBINATION

Exposure Time	Temperature Deg. C				
(Sec.)	105	115	125	135	145
5	0.25	0.50	1.50	1.00	1.00
10	0.25	1.00	1.50	16.00	15.50
15	5.50	17.00	19.50	24.50	24.75
20	22.00	20.00	24.50	24.25	24.75
25	22.25	25.00	24.25	24.75	24.75

TABLE III

STANDARD DEVIATION BETWEEN REPLICATES WITHIN EACH TEMPERATURE-TIME EXPOSURE COMBINATION

Exposure Time	Temperature Deg. C				
(Sec.)	105	115	125	135	145
5	0.58	0.41	0.58	0.82	0.00
10	0.58	0.00	0.58	3.55	1.12
15	3.10	1.22	0.58	0.58	0.50
20	0.82	2.16	0.58	0.92	0.50
25	1.60	0.00	0.87	0.50	0.50

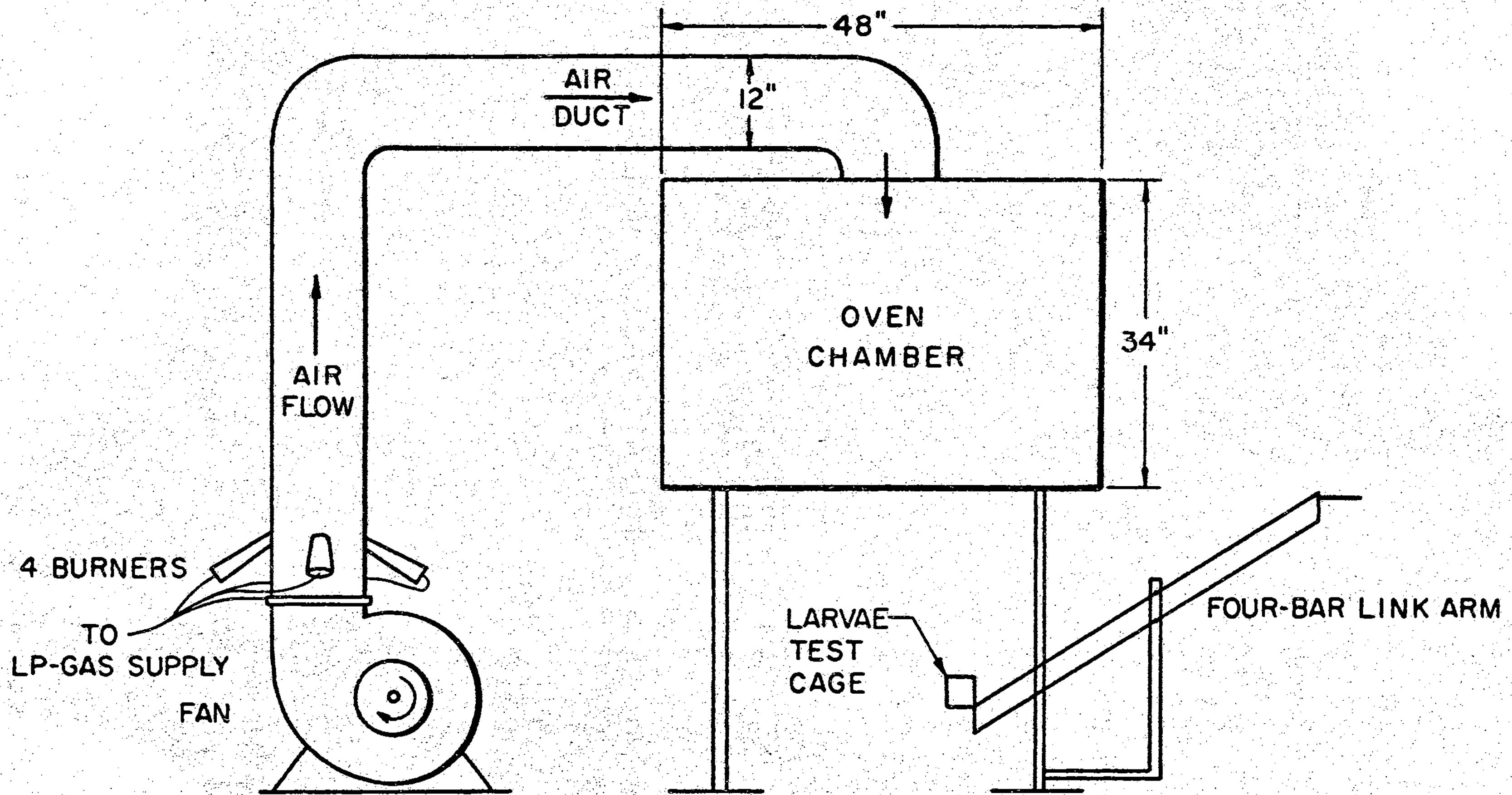

Figure 1. Schematic Diagram of the Laboratory Apparatus

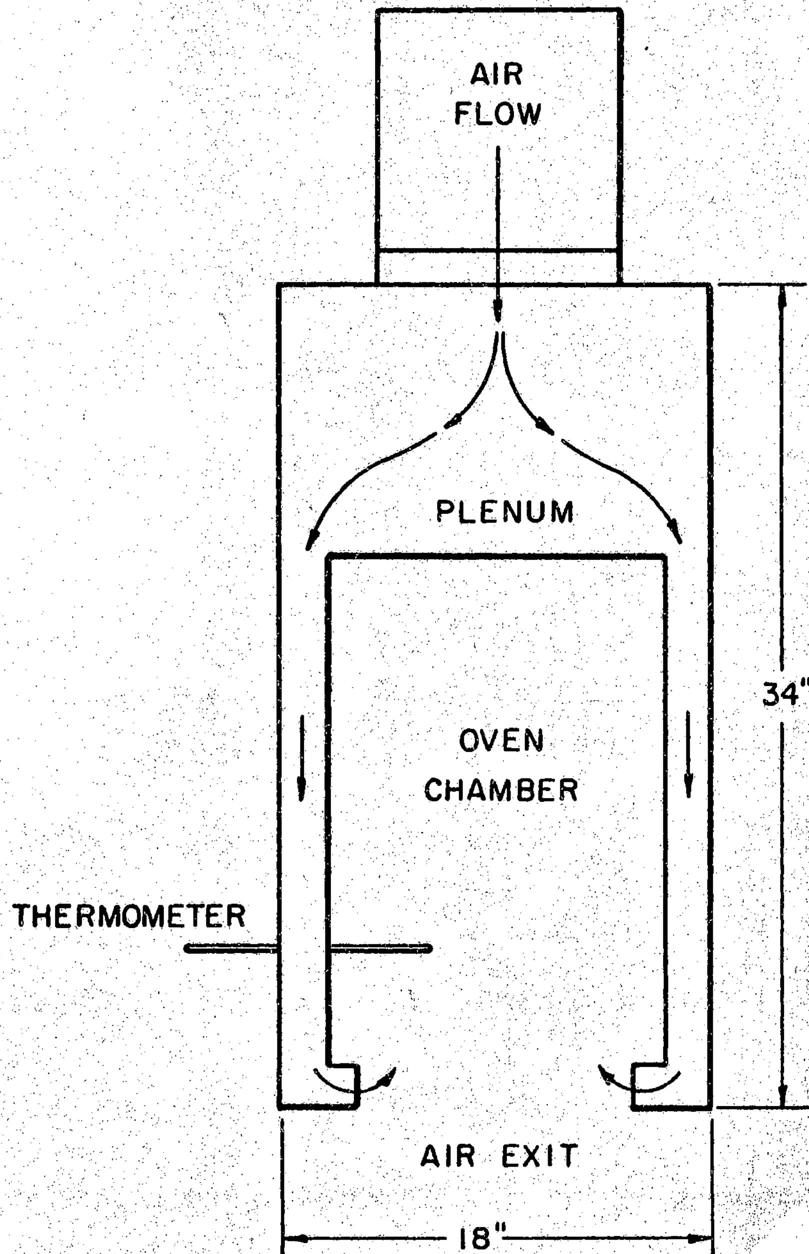

Figure 2. Cross Section of the Laboratory Apparatus Showing the Air Flow Pattern

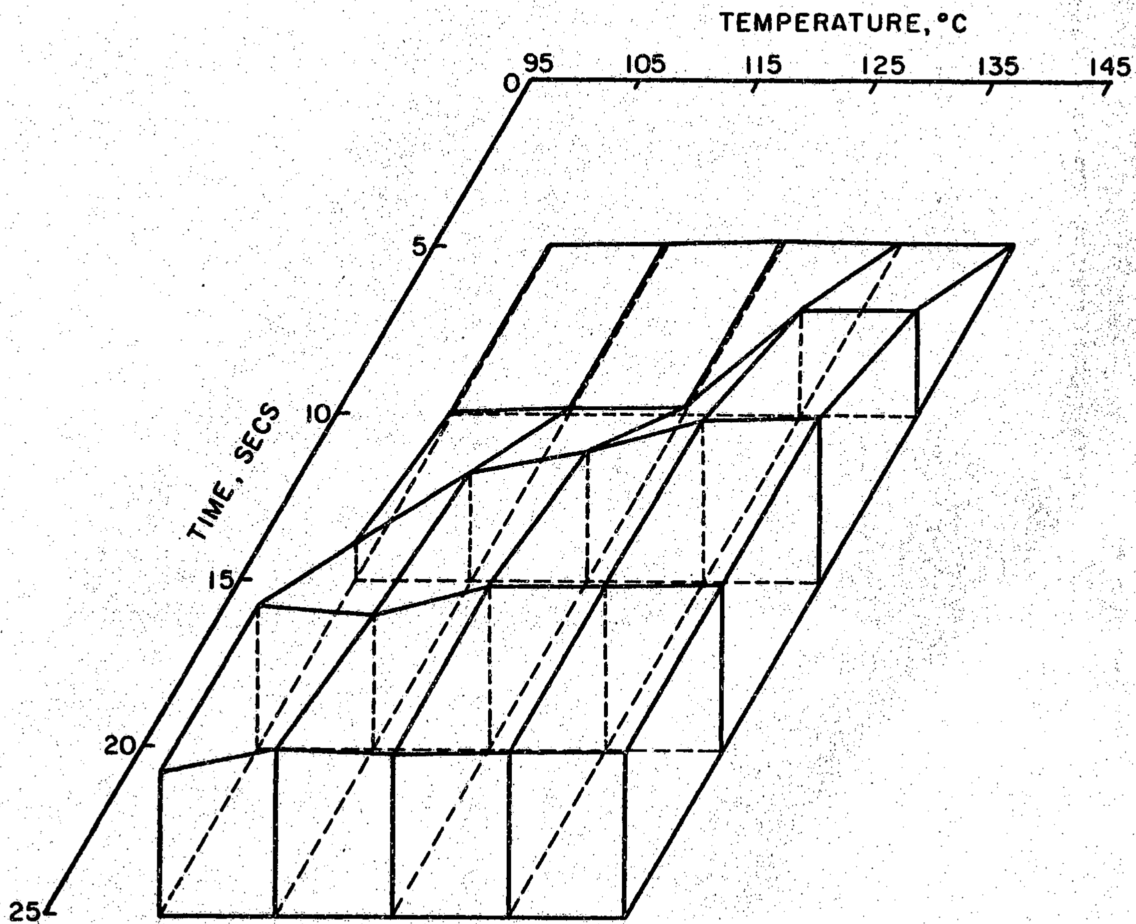

Figure 3. Three Dimensional Surface Derived From Table 2 Depicting Larval Mortality in Relation to Temperature and Time Exposure

VITA

William Bruce Massey Jr.

Candidate for the Degree of

Master of Science

Thesis: THERMAL MORTALITY STUDY ON THE BOLLWORM, *HELIOTHIS ZEA* (BODDIE)

Major Field: Entomology

Biographical:

Personal Data: Born in Broken Bow, Oklahoma, April 1, 1940, the son of William Bruce and Charlie Mae Massey.

Education: Graduated from Sherman High School, Sherman, Texas in 1958; received the Bachelor of Science degree from Oklahoma State University, with a major in Animal Science in May of 1969; completed requirements for the Master of Science degree in July 1970.

Experience: Clerk-typist for the Bureau of Indian Affairs in 1961; U. S. Naval Security Group, U. S. Navy, 1961-1966; Ordnance worker, U. S. Naval Ammunition Depot, McAlester, Oklahoma, January 1966 to September 1966; Cotton Research Laboratory Technician, Entomology Department, Oklahoma State University, 1967-1969; Graduate Research Assistant in Entomology Department, Oklahoma State University, 1969-1970.

Organizations: Tau Kappa Epsilon, Sanborn Entomology Club, Entomological Society of America.