THE BIOLOGY AND CONTROL OF THE COTTON LEAF PERFORATOR

by

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INTRODUCTION

Cotton, Gossypium hirsutum L., is the most important crop in Arizona. In recent years the cotton leaf perforator, Bucculatrix thurberiella Busck, has become an increasingly important pest of this crop in the state. The damage is done in the larval stage. The first instar larvae mine the leaves while the larger larvae attack leaves, squares, and the bracts of bolls and squares. Their feeding may cause defoliation and the shedding of both squares and bolls, often seriously reducing yield.

The studies presented here were made at Yuma, Arizona during the summer of 1955. Observations were made of the life history and habits of this pest, and parasites and predators were studied. Replicated tests were made of several insecticide formulations, and improved suggestions for control were developed.

DISTRIBUTION

In the United States the cotton leaf perforator is distributed over the arid Southwest. It has been specifically recorded from El Centro, Imperial, Brawley, Westmoreland, Calipatria, Meloland, Seeley and Calexico in California and from Yuma, Maricopa and Pinal counties in Arizona. It has also

been reported from Texas (Clancy, 1947; Essig, 1934; Folsom, 1932; Herms, 1926; McGregor, 1916; Stevenson and Kauffman, 1954). It has been reported from Peru (Lamas, 1947) and from Mexico (Essig, 1934; Folsom, 1932; Morrill, 1925). In 1955 the writer was informed of serious outbreaks in the San Luis area of northwestern Sonora, Mexico, adjacent to the Yuma area of Arizona.

PLANTS ATTACKED

The cotton leaf perforator has been reported to attack wild cotton, Gossypium thurberi Todaro (Folsom, 1932) and cultivated cotton, Gossypium hirsutum L. (Essig and Hoskins, 1934; Folsom, 1932; Herms, 1926; McGregor, 1916; Morrill, 1917). It is also reported to attack hollyhock, Althaea rosea L. (Westcott, 1946). Eggs were observed on the leaves of hollyhock under cages at Yuma, Arizona during the summer of 1955, although all failed to hatch. No eggs were observed on caged plants of Hibiscus sp.

LIFE HISTORY AND DESCRIPTION OF STAGES

During the summer of 1955 the life history of the cotton leaf perforator was observed at Yuma, Arizona on cotton plants individually caged in the field. Four plants selected for intensive observation were each about 3 feet high when first studied and had been previously caged for a one-week period to insure the absence of insect infestations. Large numbers of leaf perforator moths, collected from other fields, were placed in each cage for a 24-hour period and then removed. This produced a supply of eggs of uniform age, averaging from 90 to 100 eggs per plant. The caged plants were then observed twice daily, at 9 A.M. and 6 P.M., to note the progress of development.

Egg Stage

The very small, reticulated, vertically-ribbed, bullet-shaped eggs are about 0.28 mm. in length and hardly visible to the naked eye. They are laid singly and vertically on bolls, bracts, and on both leaf surfaces (Figure 1). They are milky white when first laid, later becoming dirty white and finally rust colored shortly before hatching. Eggs hatched in 4 to 5 days.

First Larval Instar

The full-grown first instar larvae are about 2 mm. long

Fig. 1. Diagram of egg of the cotton leaf perforator magnified approximately 125 times

Fig. 2. Tunnels in cotton leaf made by first instar larvae

and white in color. They were observed to bore and tunnel into leaf tissues at the point of egg attachment. Tunnels are about an inch long and about the same width as the larva except for an enlargement at the terminal end where molting occurs (Figure 2). These tunnels are characterized by the presence of the empty egg shell above one end and the flap-like exit hole at the other end where the second instar larva deserts the inner tissues.

The first instar larvae were observed molting inside the tunnels after feeding for 2 to 3 days. This observation agrees with those made in Arizona by Stevenson and Kauffman (1954), although McGregor (1916) reported that molting occurred outside the tunnels in the Imperial Valley, California.

Second Larval Instar

The full-grown second instar larva is 3 to 4 mm. long with two dorsal black spots on each segment, one on each side. It is green-amber in color. Larvae feed externally on upper and lower leaf surfaces, on bracts of bolls and squares. Leaves were almost completely devoured except for veins and a small amount of epidermis. In severe infestations when a great number of larvae were feeding, the leaves became brittle and dry, later dropping to the ground. After from one to 2 days of active feeding, these second instar larvae then entered an inactive period. At this time they became pale yellow and spun horseshoe-shaped webs about themselves, usually between two large veins. This period is known as the

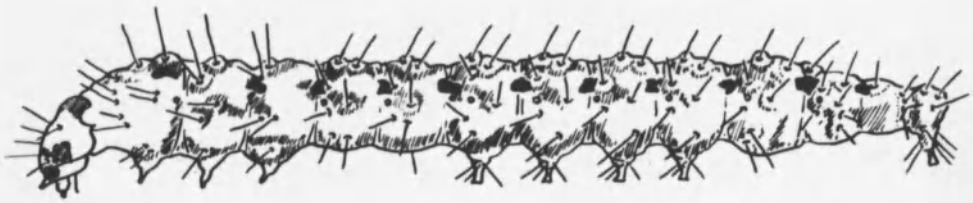

Fig. 3. Third instar larva of the cotton leaf perforator magnified approximately 24 times

"horseshoe stage." The larvae lie in a looped position with the two ends of the body in contact. After one to 2 days, molting occurred.

Third Larval Instar

Full-grown third instar larvae are cylindrical, rough-skinned, 4 to 5 mm. long, and green-amber in color. The head is triangular with black eye spots. Peterson (1951) has reported that the prespiracular setae (Kappa group) on the prothorax of third instar larvae of this genus are trisetose with the setae widely separated. In specimens of larvae of the cotton leaf perforator observed by the writer, the Kappa group has been found to contain but 2 setae. The writer observed setae alpha (1) to be above the level of setae beta (2) on all abdominal segments, although in his discussion of larvae of this genus Peterson has indicated that alpha (1) is below beta (2) on the eighth and ninth segments. Paired black spots are located dorsally on the prothorax, between the meso and meta thorax, and on the first nine abdominal segments. Spiracles are circular and located on the prothorax and on the first eight abdominal segments. Prolegs are present on abdominal segments 3, 4, 5, 6 and 10, and bear uniordinal crochets arranged in an unclosed penellipse (Figure 3).

Larvae of the third instar fed in the same manner as second instar larvae but were more aggressive (Figure 4).

Both second and third instar larvae wiggle violently when disturbed. They were seen suspending themselves from the

Fig. 4a. Typical plant injury caused by the cotton leaf perforator

Fig. 4b. Typical foliage injury produced by the cotton leaf perforator

leaves by silken threads. The third larval instar is completed in from 1 to 2 days.

Field observations during July, 1955 showed that larvae were most commonly found on the lower leaf surfaces. Of 243 larvae found on 25 leaves selected at random, 154 (63.4%) were on the lower leaf surfaces and 89 (36.6%) on the upper surfaces.

Cocoon

Shortly before making the pupal cocoon, a series of vertical "bristles" is spun and placed in a curved row on the leaf surface, outlining the area of the future cocoon. The larva starts at one end of the area and spins the first half of the cocoon by moving its head from one side to the other. Silk comes from the silk (labial) glands and is released through an opening on the underside of the head. As the cocoon develops, the distance between the spun ridges seems to be determined by the distance between the front legs of the larva, which rest on adjacent vertical "bristles" during the process. On completion of the first half of the cocoon, the larva turns around and starts at the opposite end of the area in the same manner until the two halves are joined together. Then the larva starts at one end to tighten the cocoon by weaving silken threads between the ridges from the inside. The larva turns around again and repeats the same process from the opposite end.

Larvae observed under laboratory conditions required 4

to 5 hours to spin a cocoon. Pearly-white, ribbed cocoons 5 to 7 mm. long were found on both leaf surfaces, stems, branches, and on leaves of nearby grasses (Figure 5). The pupal stage required from 5 to 6 days.

On July 25, 1955, ten plants selected at random from a single stub cotton field were examined carefully to determine the locations preferred for pupation by larvae of the cotton leaf perforator. Counts were made of the number of cocoons present on stems, branches, leaves (both surfaces), petioles, square bracts, boll bracts, and on bolls. The results of these observations are summarized in Table 1.

The greatest number of cocoons were found on the lower surfaces of the leaves; of the 472 cocoons observed, 259 (55%) were on the lower leaf surfaces.

Adult

Adult moths have a wing expanse of 7 to 8 mm. and a body length of 3 to 4 mm. The head tuft, head and thorax are white; the abdomen and hind wings are pale straw color. The antennae are filiform, many segmented, and with dark annulations. The fore wings are white, with the extreme costal edge black. The hind wings are fringed with long hairs (Figure 6).

During the period from June 30 to August 20, 1955, from four to five overlapping generations of the cotton leaf perforator were observed. All stages of the insect were seen in the field at the same time. Adults were still active as late

Fig. 5. Cocoon of the cotton leaf perforator magnified approximately 2 times

Table 1. Distribution of cotton leaf perforator cocoons on cotton plants, Yuma, Arizona; July 25, 1955

Plant no.	Number of cocoons present on							
			Leaves					
	Stems	Branches	Bottom	Top	Petioles	Square Bracts	Boll Bracts	Bolls
1	5	0	10	1	0	0	1	1
2	6	0	19	7	1	0	4	4
3	6	1	18	5	2	0	0	0
4	10	4	46	17	5	0	15	7
5	3	2	25	2	1	0	3	0
6	0	1	43	12	3	0	6	0
7	5	1	27	8	2	0	1	0
8	14	1	21	6	4	0	4	1
9	5	3	32	0	4	0	0	0
10	13	0	18	0	4	0	3	1
Total	67	13	259	58	26	0	37	14
Percent of grand total	14	3	55	12	6	0	8	3

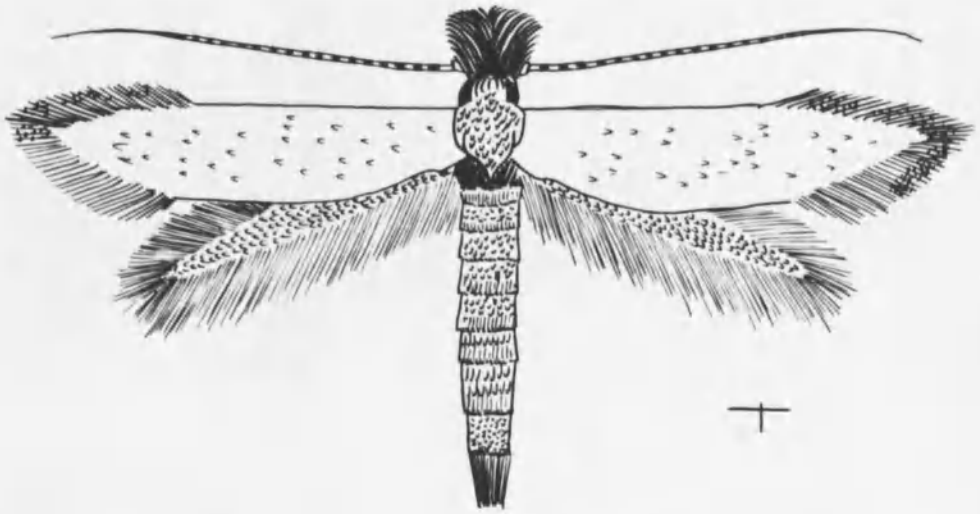

Fig. 6a. Diagram of adult of the cotton leaf perforator magnified approximately 15 times

Fig. 6b. Moth of leaf perforator in typical resting position on underside of cotton leaf

as January, 1956. Observations on the rate of development of this insect during the summer of 1955 are summarized in Table 2.

Table 2. Rate of development of the cotton leaf perforator under field conditions at Yuma, Arizona; August 1955

Stage	Number of individuals observed	Length of stage in days	
		Range	Average
Eggs	95	4-5	4.5
First instar larva	39	2-3	2.3
Second instar larva	10	1-2	1.2
"Horseshoe stage"	10	1-2	1.2
Third instar larva	6	1-2	1.2
Pupa	8	5-6	5.3
Totals		14-20	15.7

BIOLOGICAL CONTROL

No references to insect predators of the cotton leaf perforator were found in the available literature. Several observations of activity by predators during the summer of 1955 are summarized in Tables 3 and 4. Green lacewing larvae and Orius nymphs were the most active predators observed in the field.

Insect predators of the cotton leaf perforator were also collected from the fields and brought to the laboratory for study. Predators were confined individually with single representatives of each stage of the cotton leaf perforator in separate petri dishes. The predators were observed very closely, and the time required to kill each stage of the leaf perforator was recorded. An Assassin bug, Zelus sp., was observed closely for 2 hours on July 23, 1955. During this period it killed 3 third-instar larvae and one second-instar larva of the cotton leaf perforator.

Parasites

Clancy (1946) has reported the following insects as being parasitic on the cotton leaf perforator at Yuma, Arizona, although none of these species was observed by the writer during field observation in that area in 1955. Closterocerus utahensis Cwfd. (Hymenoptera:Pteromalidae) was reported to be

Table 3. Field observations of activity by predators of the cotton leaf perforator, Yuma, Arizona, 1955

Predator	Order and family	Stage of leaf perforator attacked	Date observed
Green lacewing (larva) (*Chrysopa* sp.)	(Neuroptera:Chrysopidae)	Second instar larvae	July 15
		Horseshoe stage	July 18
		Third instar larvae	Aug. 16
Orius sp. (nymph)	(Hemiptera:Anthocoridae)	Horseshoe stage	July 15
		Second instar larvae	July 15
Collops sp. (adult)	(Coleoptera:Malachiidae)	Third instar larvae	July 15
Convergent lady beetle (adult) (*Hippodamia convergens* Guerin)	(Coleoptera:Coccinellidae)	Cocoon	Aug. 10

Table 4. Laboratory observations of activity by predators of the cotton leaf perforator, Yuma, Arizona, 1955

Predator	Order and family	Larval instar of leaf perforator attacked	Ave. time (min.) required to kill the host	Range (min.)
Assassin bug (adult) (*Zelus* sp.)	(Hemiptera:Reduviidae)	Third	9	7-13
		Second	4	4
Assassin bug (adult) (*Sinea* sp.)	(Hemiptera:Reduviidae)	Second	9	9
Green lacewing (larva) (*Chrysopa* sp.)	(Neuroptera:Chrysopidae)	Third	30	30-33
		Second	5	5
Collops sp. (adult)	(Coleoptera:Malachiidae)	Third	12	10-15
Geocoris sp. (adult)	(Hemiptera:Lygacidae)	Third	38	38
Nabid (adult) (*Nabis* sp.)	(Hemiptera:Nabidae)	Third	32	17-46
Nabid (nymph) (*Nabis* sp.)	(Hemiptera:Nabidae)	Third	27	27

a minute, jet black parasite which laid its eggs in the body cavity of the first instar larvae after paralyzing them. Unparasitized larvae had typical horseshoe-shaped exuviae, while parasitized individuals were recognized by outstretched, twisted larval skins at the ends of the mines. The life cycle of this parasite during mid-summer was reported to require from 12 to 15 days. Catolaccus aeneoviridis (Gir.), Sphilochalis side (Walk.) and Haltichella sp. (Hymenoptera:Chalcididae) were reared by Clancy from cocoons. The average combined parasitism was 24.2% for all three species mentioned, although C. aeneoviridis (Gir.) was the most active, with 7.2% parasitism.

During July, 1955 individuals of various stages of the cotton leaf perforator were collected by the writer at Yuma and observed for possible parasitism. Four species of parasites were recovered. Cocoon parasites were abundant, and smaller numbers of parasites of "horseshoe stage" larvae were also found. The emerged adult parasites (all Hymenoptera) were identified by B.D. Burks of the United States Department of Agriculture.

Catolaccus victoria Burks, Family Pteromalidae, is metallic black in color, with reduced wing venation, and with one apical spur on each hind tibia. Ten specimens were reared from host cocoons.

Liodontomerus insuetus Gahan, Family Torymidae, is metallic colored, with reduced wing venation, and a very long

ovipositor. B.D. Burks states (in correspondence) that this species is primarily a parasite of the clover-seed chalcid, a common pest of seed alfalfa in the Yuma area. One specimen was reared from a host cocoon.

Polynema sp., Family Mymaridae, is a very minute insect with long filiform antennae. Hind wings are very narrow, and there are long fringes on all wings. Two specimens were reared from "horseshoe stage" larvae.

Derostenus arizonensis Cwfd., Family Eulophidae, is metallic colored with reduced wing venation and four-segmented tarsi. Five specimens were reared from "horseshoe stage" larvae.

CULTURAL CONTROL

No important alternate host plants for the cotton leaf perforator were observed in 1955, nor have important alternate host plants been reported in the available literature. Table 5 compares infestations of the cotton leaf perforator in two fields, one of which was stub cotton and the other a normally-planted field located several miles from the nearest stub cotton field.

Table 5. Larval infestations of the cotton leaf perforator in stub cotton and normally-planted cotton; Yuma, Arizona, 1955

1955	Larvae per 100 leaves	
	Stub cotton field	Normally-planted cotton field
June 29	53	0
July 6	77	2
" 13	44	0
" 20	22	4
" 27	14	8
Aug. 3	38	16
" 10	14	30
" 17	400	100
Cumulative totals	662	160

After the cotton crop is harvested different stages of the cotton leaf perforator, including eggs, larvae and cocoons, still remain on the plants. Grazing of these plants by livestock will help to destroy these individuals.

It is apparent that stub cotton should be destroyed before the next season to eliminate hibernating areas and the future food for the leaf perforator.

CHEMICAL CONTROL

During the summer of 1955, four experiments were conducted to evaluate previous insecticidal control recommendations and to test new materials in an effort to find more effective and economical insecticides for controlling the cotton leaf perforator.

In each test, randomized block designs with four replicates were used, with individual plots approximately one acre in each case.

Dusts were applied with a Hardie traction-type duster operated from the power take-off of a tractor. The tractor was usually operated in second gear with a full throttle. The duster had two movable steel booms and was capable of covering a swath 30 feet wide.

Sprays were applied with a tractor-mounted Yellow Devil, low-gallonage sprayer also operated from the power take-off. With the aid of two movable booms it was possible to spray eight rows of cotton with three nozzles per row in one operation. Sprays were applied at the rate of 10 gallons per acre at a pressure of 80 pounds per square inch using 5X nozzles.

The degree of control was measured by counting the number of second and third instar larvae (excluding the horseshoe stage) present on 50 leaves selected at random from the two

center rows of each replicate.

Experiment No. 1

The first test, of a preliminary nature, was ineffective because of low infestations. In this test the following materials were applied as dusts: 2% endrin; 15% toxaphene, 5% DDT, 40% sulfur, and 10% Perthane. Endrin and toxaphene-DDT combinations were used more effectively in later tests.

Experiment No. 2

In this test the following insecticide dust mixtures were compared with one another and with untreated plots:

1) 2% endrin, 50% sulfur
2) 15% toxaphene, 5% DDT, 40% sulfur
3) 3% chlorothion
4) 20% toxaphene, 40% sulfur.

The test was conducted in a 20-acre field of stub cotton owned by Mr. Earl Stark. All dusts were applied at the rate of 20 pounds per acre on July 13, 1955. The results are summarized in Table 6.

Although 3% chlorothion dust apparently gave better control than the other materials, the results were neither satisfactory nor statistically significant. Other dust formulations tested did not give sufficient control to be considered promising or practical.

Table 6. Effectiveness of four insecticide dusts against the cotton leaf perforator at Yuma, Arizona, 1955 (Experiment No. 2)

Materials used	Larvae per 50 leaves July 15	July 18
2% endrin	6.25 (40)*	33.00 -
15% toxaphene, 5% DDT, 40% sulfur	4.50 (57)	32.75 -
3% chlorothion	3.75 (64)	14.50 (52)
20% toxaphene, 40% sulfur	6.00 (43)	30.25 -
Untreated plots (checks)	10.50 -	30.50 -

*Figures in parentheses indicate the percentage control efficiency of the treatments according to Abbott's formula.

The observed differences between treatments were not significant according to the F test.

Experiment No. 3

In this experiment, plots treated with four spray formulations and six dust formulations were compared with one another and with untreated plots.

The following formulations of emulsifiable concentrates were applied as sprays:

1) Toxaphene + DDT (8 pounds and 2 pounds of actual toxicant per gallon, respectively
2) Endrin (1.5 pounds per gallon)
3) Chlorothion (4 pounds per gallon)
4) Methyl parathion (8 pounds per gallon).

The following dust formulations were used:

5) 2% endrin (formulated by Stauffer Chemical Company)

6) 2% endrin, 50% sulfur (formulated by Arizona Fertilizers, Inc.)
7) 15% toxaphene, 5% DDT, 40% sulfur
8) 1.5% dieldrin
9) 3% chlorothion
10) 10% DDT, 50% sulfur.

This test was conducted in a 44-acre stub cotton field owned by Mr. Earl Stark. The field was divided into 44 one-acre plots. The dusts were applied on July 22, 1955 at the rate of 20 pounds per acre; the sprays were applied July 21, 1955 at the rate of 10 gallons per acre. The actual amounts of each toxicant used per acre and the results of the experiment are given in Table 7.

In observations made four days after treatment, all spray formulations gave better control than any dust formulation. All treatments except 2% endrin dust (Stauffer) and 10% DDT-50% sulfur dust gave highly significant control when compared with untreated plots. After seven days, sprays containing chlorothion and methyl parathion were apparently the most effective, although there was no statistically significant difference between any of the spray treatments. Formulations of endrin and toxaphene plus DDT gave good control. None of the dust formulations was effective seven days after application.

Table 7. Effectiveness of various spray and dust formulations against the cotton leaf perforator at Yuma, Arizona, 1955 (Experiment No. 3)

Material	Pounds of actual toxicant used per acre	Larvae per 50 leaves	
		July 25-26	July 28-29
Sprays - applied July 21			
Toxaphene + DDT	2, 1	7.75 (93)*	35.00 (78)
Endrin	0.3	6.25 (94)	35.50 (78)
Chlorothion	0.25	5.75 (95)	13.75 (91)
Methyl parathion	1.00	0.75 (99)	14.25 (91)
Dusts - applied July 22			
2% endrin (Stauffer)	0.4	139.00 -	408.50 -
2% endrin (Arizona Fertilizers)	0.4	53.25 (53)	149.75 -
15% toxaphene, 5% DDT, 40% sulfur	3, 1, 8	48.50 (57)	106.75 (32)
1.5% dieldrin	0.3	48.50 (57)	134.50 (15)
3% chlorothion	0.8	49.25 (56)	107.75 (32)
10% DDT, 50% sulfur	2, 8	114.25 -	151.00 -
Untreated plots (checks)	--	112.25	158.00
Difference required for significance: 1%		32.72	139.89
5%		24.29	103.87

*Figures in parentheses indicate the percentage control efficiency of the treatments according to Abbott's formula.

Experiment No. 4

In this test the following four emulsifiable concentrates were compared with one another and with untreated plots:

1) Toxaphene + DDT (4 pounds and 2 pounds of actual toxicant per gallon, respectively)
2) Endrin (1.6 pounds per gallon)
3) Methyl parathion (8 pounds per gallon)
4) Aldrin (2 pounds per gallon)

A field of stub cotton owned by Mr. Elliot Waits was divided into 20 plots of one acre each. Sprays were applied on August 8 and 18, 1955 at the rate of 10 gallons per acre. The actual amount of each toxicant used per acre and the results of the experiment are shown in Table 8.

Two days after the first application, all sprays gave good control although there was no statistical significance between treatments. Five days after application, methyl parathion gave the best control when compared with untreated plots. Endrin and toxaphene plus DDT treatments also gave good control, but aldrin lost its effectiveness. Eight days after the first application endrin, toxaphene plus DDT, and methyl parathion gave good control. Two days after the second application, methyl parathion apparently gave the best control, although there was no statistical difference between the various treatments.

Table 8. Effectiveness of sprays prepared from four emulsifiable insecticide concentrates against the cotton leaf perforator at Yuma, Arizona, 1955 (Experiment No. 4)

Materials, (applied Aug. 8 & 18)	Pounds of actual toxicant used per acre	Larvae per 50 leaves			
		No. days after 1st application			No. days after 2nd application
		2	5	8	2
Toxaphene + DDT	2.1	8.75 (77)*	14.20 (67)	29.75 (63)	16.25 (97)
Endrin	0.3	6.00 (84)	10.75 (75)	38.75 (51)	51.00 (89)
Methyl parathion	0.5	1.00 (97)	5.00 (89)	3.50 (96)	6.00 (99)
Aldrin	0.3	4.75 (87)	22.50 (48)	92.25 -	100.50 (79)
Untreated plots (checks)	---	37.25 -	43.50 -	79.75 -	478.50
Difference required for significance:	1%	29.63	33.02	38.61	301.98
	5%	21.13	21.79	27.54	215.39

*Figures in parentheses indicate the percentage control efficiency of the treatment according to Abbott's formula.

SUMMARY

The life history and control of the cotton leaf perforator, Bucculatrix thurberiella Busck, an increasingly serious pest of Arizona cotton, were investigated at Yuma, Arizona during the summer of 1955. Original observations were made on the rate of development, biology and appearance of individuals of the various stages of the life cycle. Five successive generations were observed during the period from June 30 to August 20, 1955, although there was much overlapping among generations.

Green lacewing larvae and Orius nymphs were the most active predators in the field. Six species of native predators were also studied further in the laboratory. Native parasites were present but were not effective in reducing infestations.

Leaf samples collected from a field of stub cotton (second year growth) contained more than four times as many larvae over an eight-week period as similar samples from an isolated, normally-planted field, emphasizing the undesirability of the practice of growing stub cotton.

After four large-scale field control tests, it was concluded that spray formulation insecticides were more effective than dust formulations. Liquid formulations of methyl

parathion, chlorothion, endrin, and toxaphene plus DDT were found to be effective, although more than one application was required for adequate control of heavy infestations.

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