AN EVALUATION OF A COTTON INSECT CONTROL PROGRAM BEING USED IN THE PECOS VALLEY OF TEXAS

By

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PREFACE

Since cotton acreage allotments went into effect in 1953 much more emphasis is being put on insect control. Each summer students from Oklahoma Agricultural and Mechanical College participate in supervised insect control programs conducted on irrigated cotton throughout different parts of West Texas. Dr. F. A. Fenton, Professor of Entomology and Head Emeritus of the Department of Entomology, Oklahoma A. and M. College has worked diligently in selecting and placing the writer and many other students in this work. The author has been participating in supervised cotton insect control programs since 1953 and feels that he has received valuable experience in this field of endeavor. With these facts in mind, Dr. Fenton suggested that I study the records from my work of the past two summers and write a thesis from this material. I have attempted to evaluate the control program that I followed along with a detailed ecological study and control measures applied.

The author wishes to express his appreciation to his major advisor, Dr. F. A. Fenton, for his valuable assistance and careful guidance in the preparation of this paper. Also, much guidance on preparation and constructive criticisms of this manuscript was received from Drs. D. E. Howell, Professor of Entomology at Oklahoma A. and M. College, R. R. Walton, Professor of Entomology, D. E. Bryan, Associate Professor of Entomology and J. E. Thomas, Associate Professor of Botany and Plant Pathology.

Indebtedness is also acknowledged to the following specialists:- Kellie O'Neill, P. W. Oman, Louise M. Russell, and H. W. Capps, United States Department of Agriculture Insect Identification and Parasite Introduction Section, for identification of thrips, aphids, lepidopterous larvae and many pinned specimens:- to Harvey Hamilton, student, for assisting in graph drawings, to Messrs. James Stanford, graduate student, Robert Stanford and Glen Mooney, students, for helpful suggestions and planning of work.

Harold E. Stanford

TABLE OF CONTENTS

INTRODUCTION

During the summers of 1953 and 1954 the writer was employed respectively at Lubbock and Pecos, Texas by two cotton insect survey organizations who advised their clients on the current insect infestations in their fields. During the past two seasons he has managed his own service at Pecos, Texas, called the Stanford Entomology Service. The main purpose of the inspection service was not only to take infestation records, but to give control recommendations if needed. This service consisted of inspecting the customers' cotton fields 3 times each week for a 13-weeks period for which each farmer paid $1.30 per acre. The total acreage under contract was 2550 in 1955 and 4400 in 1956. During these years a detailed set of notes was kept of the insect infestations in this area. A study and interpretation of these records has been used as the subject matter of this thesis.

The area included in this survey extends roughly from Balmorhea to Pecos, Texas, and comprises approximately 54,000 acres of irrigated cotton (Fig. 1). This area can be described as a treeless plain that slopes slightly from the Davis Mountains, south of Balmorhea, to and beyond Pecos.

According to the U. S. Weather Bureau data, the average annual rainfall for the last two years was considerably below normal. Rainfall in 1955 totalled 8.03 inches and was 2.31 inches in 1956 (Tables

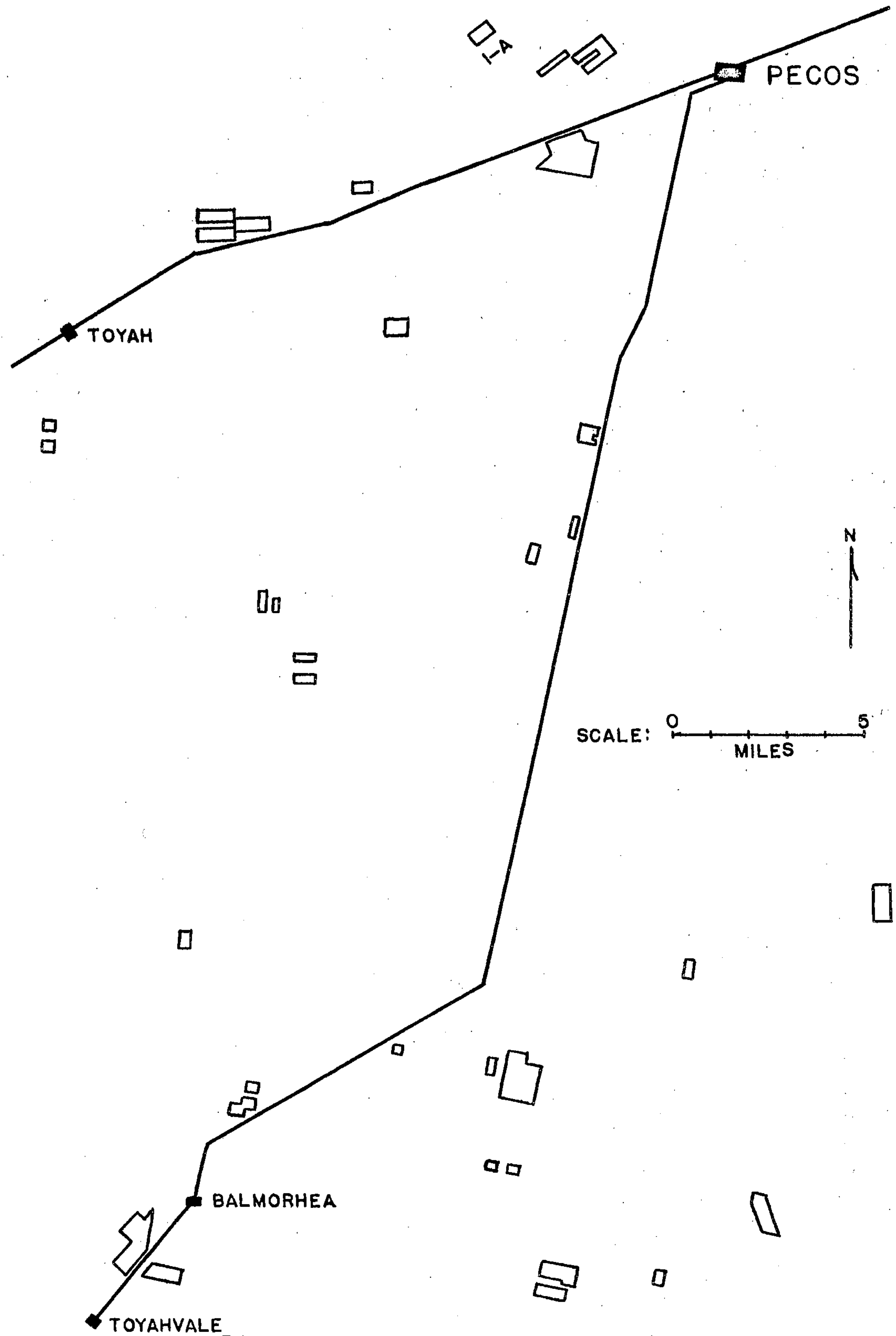

FIG.1—MAP OF PECOS AGRICULTURAL AREA

1, 2). Cotton farmers in this area depend entirely on irrigation water for growing their crops. The average growing season is 232 days long with the first killing frost around November 5.

The average temperatures for the Pecos Area during June, July and August is 81.7 degrees (Tables 1, 2). In 1956 the temperatures were 3.4 degrees above normal and in 1955 they were 0.3 degrees above normal. This area is characterized by having warm nights (66 degrees average) which are favorable to plant growth during this time.

With these favorable climatic conditions plus the development of deep well irrigation which started in 1946, the Pecos Valley has become one of the major cotton raising districts in the United States. The cotton industry about Pecos developed very slowly. By trial and error, through these times, it was discovered that the long staple[1] cotton with exceptional fiber strength could be more successfully grown in the Pecos area than any point in the "Old South". The principal variety grown, which was developed particularly for that region, is Acala 1517. Pima, a variety with extremely long staple ($1\frac{1}{2}$" plus), which was developed in Pima, Arizona, is also grown to a limited extent.

As irrigation and the growing of improved cotton varieties were established resulting in a marked increase in cotton acreage, the insect problem also increased. As insect damage increased, many farmers attempted to overcome losses due to insects by overplanting. However, farmers became more interested in insecticidal control.

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[1]Acala and Pima both were considered long staple cotton.

Table 1 - Climatological data for the Pecos Area, 1955*

Month	Temperature Degrees Fahrenheit								Inches Rainfall	
	Mean			Extremes						
	Max.	Min.	Avg.	High	Date	Low	Date	Departure From Normal	Total	Departure From Normal
January	56.7	27.7	42.2	78	5	10	10	-3.3	0.79	0.32
February	65.6	27.9	46.8	79	28	15	11	-1.5	0.00	-0.29
March	76.8	37.0	56.9	90	15	19	28	0.7	0.00	-0.49
April	86.2	47.0	66.6	100	23	35	2	1.1	0.00	-0.74
May	92.0	57.2	74.6	103	25	44	12	1.7	0.35	-0.67
June	98.9	62.8	80.9	110	9	55	10	0.2	1.82	0.64
July	97.0	68.1	82.6	105	9	63	18	0.3	1.81	0.42
August	96.8	68.0	82.4	105	10	62	29	0.4	0.15	-0.89
September	93.0	62.9	78.0	100	4	52	2	3.7	2.55	0.69
October	84.0	48.0	66.0	98	1	36	30	0.9	0.56	-1.01
November	70.4	36.0	53.2	88	1	21	29	1.1	0.00	0.58
December	64.5	30.3	47.4	84	25	15	9	1.9	0.00	-0.54

*Based on records from the Pecos Weather Bureau Station.

Table 2 - Climatological data for the Pecos Area, 1956*

Month	Temperature Degrees Fahrenheit: Mean Max.	Mean Min.	Avg.	Extremes High	Date	Low	Date	Departure From Normal	Inches Rainfall: Total	Departure From Normal
January	63.2	28.4	45.8	81	28	18	13	0.3	0.40	-0.07
February	62.8	29.1	46.0	88	24	12	4	-2.3	0.00	-0.29
March	76.5	38.6	57.6	90	31	19	8	1.4	0.05	-0.44
April	81.0	46.7	63.9	100	27	35	4	-1.6	0.10	-0.64
May	96.0	59.9	78.0	106	13	50	6	5.1	0.22	-0.80
June	102.8	69.3	86.1	110	15	63	12	5.4	0.60	-0.58
July	102.1	69.6	85.9	110	5	65	22	3.6	0.78	-0.61
August	100.2	66.6	83.4	106	9	60	22	1.4	0.00	-0.04
September	96.4	58.7	77.6	105	16	46	10	3.3	0.11	-1.75
October	88.8	50.3	69.6	99	1	30	31	4.5	0.05	-1.52
November	68.8	30.7	49.8	86	12	15	22	-2.3	0.00	-0.58
December	65.1	29.5	47.3	80	6	16	27	1.8	0.05	-0.49

*Based on records from the Pecos Weather Bureau Station.

In the fall of 1953 cotton acreage control went into effect in the Pecos area. Until acreage allotments were passed very little emphasis was given to complete insect control. As the acreage devoted to cotton was lowered, most farmers began to use more fertilizer and irrigation water to increase their yields thus offsetting losses of total cotton production. This resulted in better cotton being grown throughout the Pecos Valley. The cotton plants grew rapidly producing an abundance of succulent vegetative and fruiting structures. This condition proved very favorable for many insects and they began to cause increasing damage in this area.

With greater emphasis being put on cotton yields the amount of insecticides used increased rapidly. According to records of the Western Cotton and Oil Company, the cost of insect control in the Pecos area increased from $4.00 per acre in 1948 to approximately $30.00 per acre in 1956. This rising cost of insect control can be correlated with the higher yield of cotton growers received from 1948 to 1956. This increase, in yield, is definitely not due to insect control alone. The amount of fertilizer and the planting of better adapted varieties has also been very important in increasing the cotton production in the Pecos Valley. This information does indicate that the rising total cost of insect control is economical, in relation to yield if the insects are present in large enough numbers to warrant poisoning.

During the inspection periods of 1955 and 1956 it was found necessary to treat all of the contracted cotton with one or more insecticide formulations.

Review of literature

During the two-year period when the writer operated a cotton insect inspection service in the Pecos area there were five major insect pest control problems which had to be solved. Information pertaining to the ecology and control of these pests is very extensive. The literature which has the most important bearing on this thesis is herewith cited.

Detailed studies on the biology of the bollworm were made by Quaintance and Brues (1905). They stated that oviposition usually occurred between sunset and darkness with the average incubation period being 2 to 3 days. They found that the larva usually molts six times and the life cycle was completed in from 30 to 35 days in the cotton belt. Many workers have published their results on control with various insecticides notably Gaines and Dean (1948) and Owens and Gaines (1952). From all of this previous work has come the fact that DDT is one of the most effective insecticides which can be used against this species. The species name has been changed many times and is now recognized as Heliothis zea (Boddie).

Although cotton has been mentioned by numerous writers as a host plant of the cabbage looper, Trichoplusia ni (Hbn.), very little has been published dealing directly with the biology of the loopers on cotton. On other crops several writers have studied and published its biology in detail. McKinney (1944) found the egg incubation period on lettuce to be from 3 to 10 days. He stated that the looper passes through 4 or 5 instars and completes the feeding period in from 10 to 50 days. Much work has been done concerning insecticide control of this pest. Hervey et al. (1954, 1956) found that endrin controlled the looper much more effectively than DDT.

Faulkner (1952) conducted a study concerning the biology and habits of the cotton fleahopper, Psallus seriatus (Reut.), and three lygus species namely, Lygus hesperus (Knight), Lygus elisus (Van D.), and Lygus oblineatus[1] (Say.) in the Pecos Valley. He stated that the average incubation period for the cotton fleahopper egg was seven days followed by five nymphal instars before reaching maturity. He found that the egg incubation period of the above lygus bugs was from 1 to 2 weeks long, there were five nymphal instars and the life cycle required approximately three weeks.

Research over a number of years in Oklahoma indicates that efforts to control the cotton fleahopper are generally unwarranted. In these tests there was no evidence that this insect alone reduces yields (Brett 1946). Reinhard (1926) made an extensive biological study of this pest and claimed it to be more serious than the boll-weevil in some areas of Texas. Painter (1930) found that fleahopper injury to the tissues of the cotton plant was very severe.

Eyer and Medler (1942) found that these species of lygus bugs and fleahoppers could be controlled with calcium arsenate and sulfur. More recent work by Parencia & Cowan (1953), and Glick & Lattimore (1954) showed that DDT would more effectively control these pests.

Information concerning the biology of the thrips Frankliniella occidentalis (Perg.) has been observed and studied by workers in Cali-

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[1]Now called Lygus lineolaris (P de B).

fornia. Bailey (1938) found the egg stage to be 15 days in early spring and five days during the summer. Under laboratory conditions Bryan and Smith (1956) found the incubation period to be four days long at 26.7 degrees Centigrade. The life cycle periods they studied ranged from 13.9 to 44.2 days at different temperatures.

Results of chemical control tests by Gaines (1934), Fletcher and Gaines (1939), Fletcher *et al.* (1947), and Gaines *et al.* (1947, 1948, 1951) indicated that insecticides reduced the thrips injury but failed to produce an increase in total yield of cotton.

INSPECTION METHODS USED

The inspection service was sold to 14 different farmers in 1955 and 23 in 1956. These people operated farms within an area of 30 square miles (Fig. 1). The writer made all of the field counts in 1955 but in 1956 due to the large number of acres contracted he was assisted by another field checker. Each field checker inspected approximately 1100 acres each day. It took approximately 25 minutes for each 100-plant count which, as shown below, was the unit for each 50 acres. Each field checker worked about 11 hours, 6 days each week. This included the inspection time in the field plus the driving time between check points.

Each field was inspected three times every week starting June 11 and ending September 9. Counts were taken at 5 points selected at random on each 50 acres in a given field. At each point counts were made on 20 plants or a total of 100 plants per 50 acres.

The size of the fields ranged from 13 to 732 acres and a minimum of 100 plants was examined from each field. The counts included eggs or other life stages of all harmful and beneficial insects which were present on the cotton plants. Each count was recorded on report forms which were made up for the individual farms (Table 3). These reports contained the actual infestation counts for each insect found.

TABLE 3—STANDARD REPORT FORM FOR INSECT RECORDS

STANFORD ENTOMOLOGY SERVICE

DATE________________________________

OWNER'S NAME________________________________

BETWEEN THE HOURS OF________________________________

INSECT INFESTATION IS AS FOLLOWS PER 100 PLANT COUNTS:
(REFER TO MAP FOR LOCATION)

BOLLWORM				
Worms	Worms Small	Eggs New	Eggs Old	
No. 1				
No. 2				
No. 3				
No. 4				
No. 5				
No. 6				
No. 7				
No. 8				
No. 9				

Aphids	Thrips	Lygus
No. 1		
No. 2		
No. 3		
No. 4		
No. 5		
No. 6		
No. 7		
No. 8		
No. 9		

Red Spider	Fleahopper	C. Loopers	Leaf Worms	Stink Bugs	Predators
No. 1					
No. 2					
No. 3					
No. 4					
No. 5					
No. 6					
No. 7					
No. 8					
No. 9					

REMARKS: ________________________________

N

W E

S

SIGNED________________________________

Infestation Counts of Injurious Species

Infestation counts were made on several insect species found in the area. The number of insects on 100 plants was recorded for the cotton bollworm, cabbage looper, cotton fleahopper, lygus bugs, and two species of stink bugs *Chlorochroa uhleri* (Say) and *C. ligata* (Say). The number of eggs and larvae of the bollworm and cabbage looper were also counted. In addition, infestation counts were made for the nymphs and adults of the cotton fleahopper, lygus and stink bugs. All other harmful and beneficial insect populations were recorded as "light", "moderate", or "heavy".

The criteria used in determining whether a farm should receive chemical treatment or not depended on many factors such as infestation percentages, climatic conditions, condition of crop and number of predators. The infestation percentage was the major factor used in giving control recommendations. The methods used depended upon the species found.

Cotton Bollworm - Counts were made on the number of white and brown eggs and small, medium and large larvae. The top one-third of each count plant was carefully examined for eggs and larvae since it was found that most of these stages were restricted to this part of the plant. Eggs were classified as new and old. This classification was based on their color. The new eggs were white in color and less than one day old. The so-called "old eggs" were brown in color and were laid more than one day before being counted.

Small larvae were usually found in terminals, small squares and blooms. Those classed as small were in the first and second instars. The medium sized larvae included the third and fourth instars. Those classed as large larvae were between the fourth stage of development and pupation in the soil.

Whenever 6 larvae were found on 100 plants, control recommendations were given. This was called a 6 percent infestation. Control was also recommended when 4 or 5 percent larva infestation and a high egg infestation (10-15) was present. In no case were control recommendations based on numbers of moths or eggs alone.

<u>Cabbage Looper</u> — The infestation counts for the cabbage looper were made very much like the bollworm counts. However, the procedure in giving recommendations was completely different from the bollworm. Counts were made on the total number of eggs and the number of small and large larvae. The age of the looper eggs could not be determined in the field and all were recorded in a composite manner. The small larvae were those from hatching up to half grown, older larvae were classified as large when being recorded.

The procedure in giving control recommendations varied somewhat due to the large number of loopers present. The amount of damage and size of the loopers were taken into consideration in determining when to poison. If the plants were showing excessive damage a residual poison was kept on the plants until heavy feeding was over or until the numbers were reduced. The recommendations were aimed at controlling the small loopers which were much easier to kill. In general, control measures were recommended when an average of 30-40 loopers were found on each 100 plants inspected. No control measures were recommended if the great majority of the larvae were over half grown because of their resistance to insecticides. The presence of looper eggs had little influence on the recommendations because the hatching dates were very difficult to determine by field observation.

Lygus Bugs - Because of their habits, which will be discussed later in this paper, the lygus bugs were very difficult to count and record. Counts were made as accurately as possible and insecticide control was recommended when 10-12 nymphs or adults were found to each 100 plants inspected.

A few of the fields that were checked were adjacent to or near alfalfa fields. Sweepings were made in the latter crop just before it was cut. This was to determine the possibility of heavy infestations of lygus migrating into the cotton fields. This condition came up twice in 1956 and a border treatment of approximately 20 yards wide was recommended.

Cotton Fleahopper and Stink Bugs - The counts were taken in the same manner as for the others described previously and the infestation percentages were recorded. When 15 to 20 nymphs or adults of the cotton fleahopper or stink bugs were present on each 100 plants, control was recommended.

The Climatic Factor

Weather conditions at the time of application markedly influenced the effectiveness of insecticide treatments. In some cases the time of treatment and the type of formulations used were determined by the prevailing weather. During June, July and August, 1956, very little dew was present on the cotton leaves. The relative humidity was so low during this time that the dust mixtures would not adhere to the leaves and spraying was recommended in several cases. Also, the wind velocity influenced the poisoning dates somewhat. In most cases, application was made during the early morning hours while the air was relatively calm and humidity conditions more favorable.

Plant Fruiting Conditions

The crop condition and the date of the season were important in determining the farmers' acceptance of control recommendations. The cotton plants loaded well during the early part of 1956 but the probability of shedding of forms caused growers to be less receptive to control measures than later in the season.

The use of shedding of fruit as a factor in determining when to poison was very debatable in the Pecos Valley area. General estimates showed no correlation between number of flowers produced and the final number of folls set on the plants. The shedding of fruit was observed very closely but was considered of minor importance in this area.

Presence of Beneficial Species

The value of predaceous and parasitic insects was considered in making control recommendations. However, this factor seems to be greatly over rated by some in the Pecos Valley area. A few farmers purchased ladybird beetles with the idea that they would control any number of harmful cotton insects and were very disappointed in their results. Beneficial insects naturally occuring in the fields delayed or made unnecessary some poison applications. During the first three weeks in June, 1956, the value of predators, chiefly *Orius* spp. and *Hippodamia* spp. was very great due to the large numbers present. Later on in the season, when the cotton crop had been poisoned, their numbers decreased considerably.

ECOLOGICAL STUDY OF MAJOR PESTS

A list of the more common cotton insect and arachnid species found in this area is given in Table 4. The list is made up of major and minor cotton pests and the beneficial forms found in cotton. The major pests were so designated because of the large amount of damage they caused during 1955 and 1956.

Cotton Bollworm

In the Pecos area, bollworm moths were first observed June 17, 1955, and June 11, 1956. They were commonly observed flying during the late afternoon and early morning hours and their crepuscular activity was demonstrated by trap lights. This crepuscular activity has been noted by several writers.

The moths were attracted much more to rapidly growing cotton plants than they were to slow growing ones. This meant that in fields where moisture and temperature were right for rapid growth in plants a great increase in bollworm moth populations usually followed. A good example of this condition is shown in Figure 2. Approximately two days after the cotton had been irrigated an abundance of new succulent growth was present. Freshly laid bollworm eggs were found in this area in large numbers. On cotton that had been watered five days previous to inspection, small bollworms were found hatching, along with a few old eggs present. The dry cotton was practically

Table 4.-The most common insect and arachnid species found in Pecos cotton fields, 1955-1956.

Harmful
Beet armyworm, *Laphygma exigua* (Hbn.).
Cabbage looper, *Trichoplusia ni* (Hbn.)*
Cotton bollworm, *Heliothis zea* (Boddie)*
Cotton fleahopper, *Psallus seriatus* (Reut.)*
Cotton leafworm, *Alabama argillacea* (Hbn.).
Cotton square borer, *Strymon melinus* (Hbn.).
Flower Thrips, *Frankliniella occidentalis* (Perg.).
Lygus bug, *Lygus* spp.*
Melon aphid, *Aphis gossypii* (Glover).
Spider mite, *Tetranychus* spp.
Stink bug, *Chlorochroa uhleri* (Say) and *C. ligata* (Say).
Beneficial
Big-eyed-bug, *Geocoris* spp.
Collops beetle, chiefly *Collops quadrimaculatus* (Fab.).
Flower bug, *Orius insidiosus* (Say) and *O. tristicolor* (Say).
Ground beetle, *Carabidae* spp.
Hooded beetle, *Notoxus* spp.
Lacewing, *Chrysopa* spp.
Lady beetle, *Hippodamia convergens* (Guer) and *Olla abdominalis* (Say).
Spiders, Araneida spp.

*Of major importance during 2-year period.

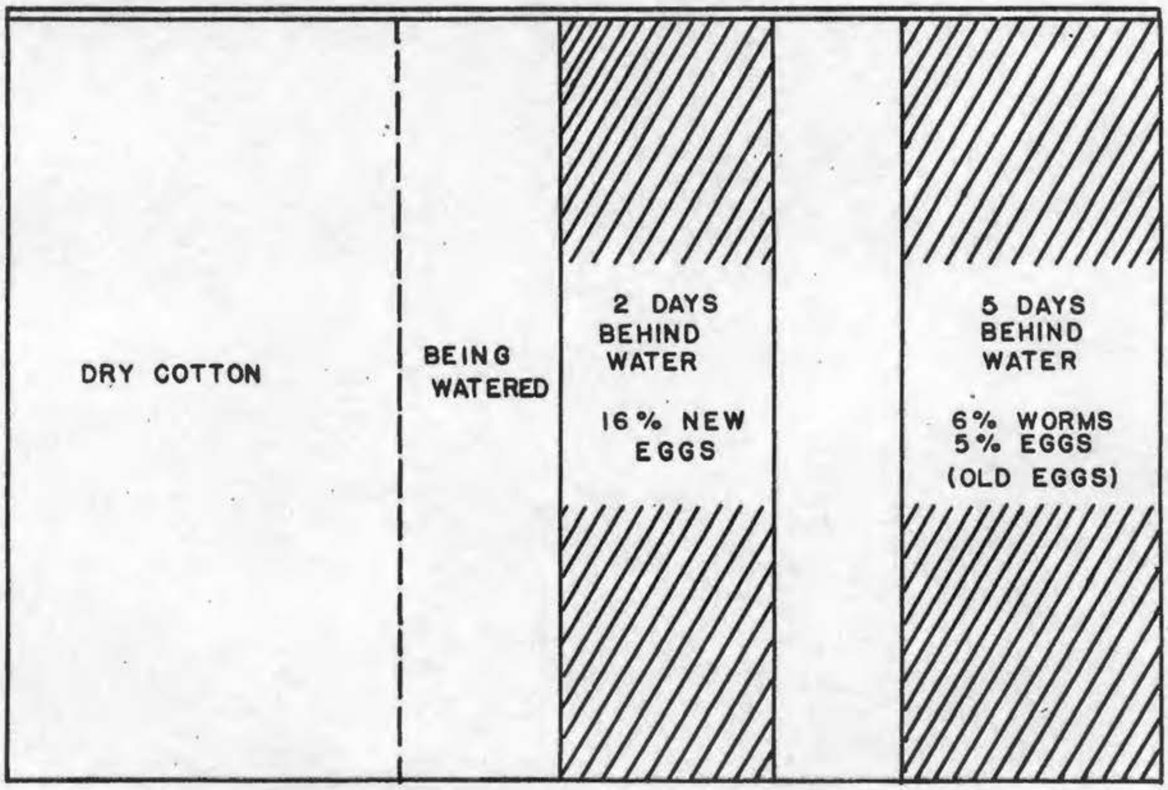

FIG. 2— TYPICAL BOLLWORM MIGRATION BEHIND IRRIGATION WATER.
JULY, 1956. PECOS, TEXAS.

free of bollworm infestations throughout this period of time. Migration of bollworm moths behind irrigation water was very common in the Pecos area during 1955 and 1956.

Egg deposition usually started very quickly after the moths were first noticed flying about in the fields. Eggs usually occurred on the upper one-third of the plants and most frequently on the new growth present. The eggs appeared white the first day after deposition. They turned brown as they got older, and the usual sequence was hatching and small larvae three days after large numbers of white eggs were recorded.

In 1955, very few bollworm moths or eggs were seen during June. The small number of eggs that occured then were fed upon by the flower bug, Orius spp. and other predaceous insects. Only a few larvae were found during this time and few of these survived to reach the late instars. Early in July, the egg infestation increased very rapidly and the predators present did not control the larvae that hatched.

Approximately 80 percent of the farms that we checked, in 1955, showed 3 or 4 noticeable egg population peaks. The records for the Bill Water's Farm (Fig. 3) are indicative of the trend observed on many farms in 1955. The location of this farm is shown as 1-A in Figure 1. Usually two of these peaks occurred in July and two more in August. The greatest number was found on August 10. Very few eggs were found in September of 1955.

During 1956, bollworm eggs were found a few days earlier than in 1955. However, the number of eggs usually did not exceed 4 or 5 per hundred cotton plants during June. Those found during this time

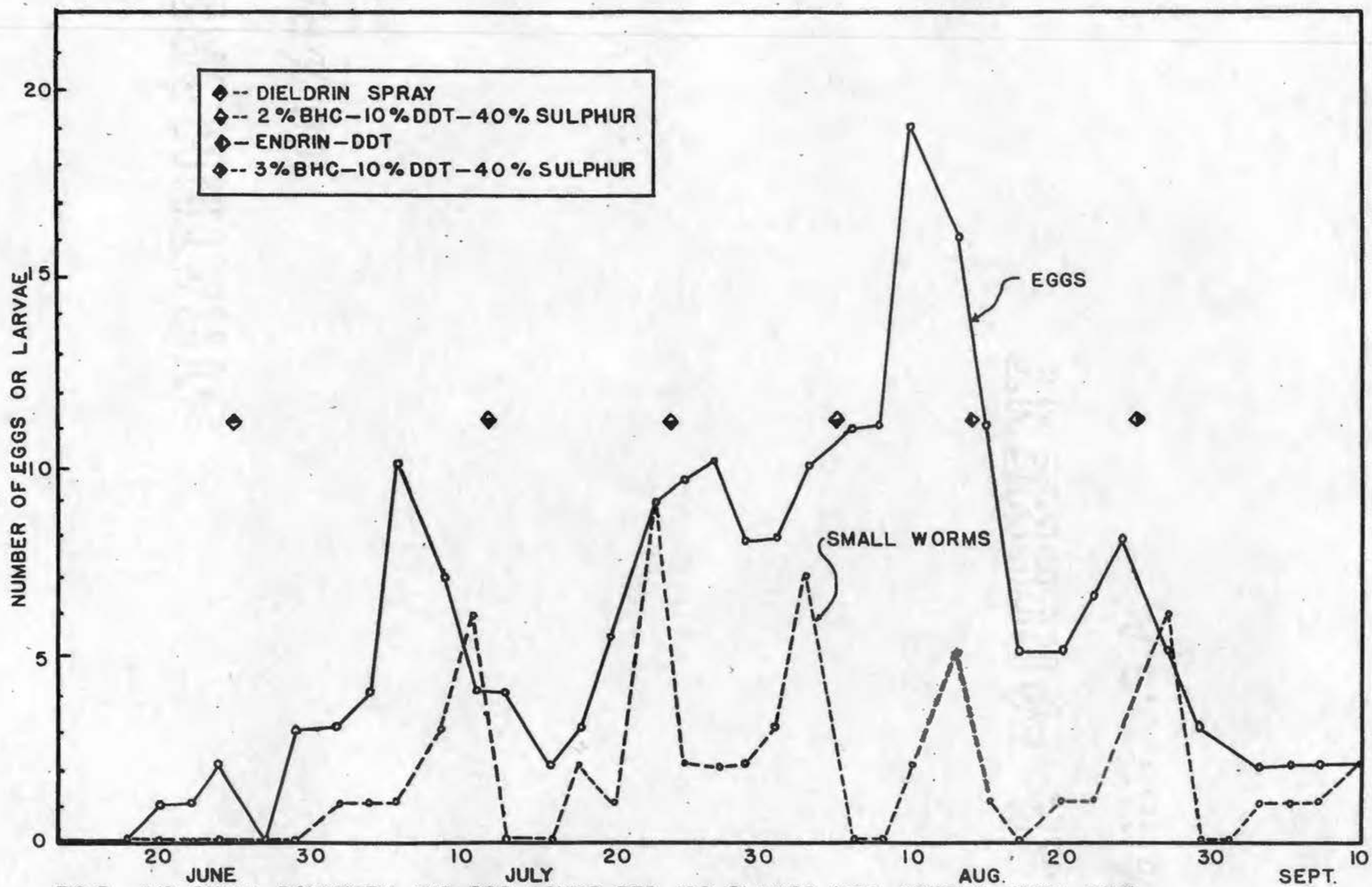

FIG. 3.—AVG. SMALL BOLLWORM AND EGG COUNT PER 100 PLANTS (BILL WATERS FARM, 1955)

were usually eaten by predators. On the T. R. Chenoweth farm, inspected June 19, 1956, an average of 17 lady beetles and 5 flower bugs were controlling a 3 percent egg infestation. These predators were observed feeding on the bollworm eggs and the hatching of larvae was not successful. The above condition was very typical through the month of June. However, when this balance was upset in some of the fields, the egg infestation increased and the bollworm larvae had to be controlled by chemical methods.

The egg infestation, in 1956, followed a similar pattern as it did in 1955 as shown by the records taken on the Dan Brijalba farm (Figure 4). However, eggs occurred in larger numbers throughout the summer and several were found in early September. Many of these eggs observed in September turned black instead of the usual brown color. Many never hatched and this was thought to be due to the cool nights that occurred at this time.

After emerging from the egg shell some of the small larvae eat the shells from which they hatched. This was observed in several instances. The young larvae feeds at first near its hatching place, then begins to wander away, crawling from one leaf to another, until a young bud or boll is found, into which it bores. In the Pecos area, the first 3, 4 or more days are spent feeding on the upper portions of the plant. It was at this early wandering, leaf feeding stage, that control measures were directed. Also, at this time, many small larvae were killed by their natural enemies such as lady beetles and their larvae and other predaceous insects. Rarely was more than one larva of the same size found on a single plant for any considerable

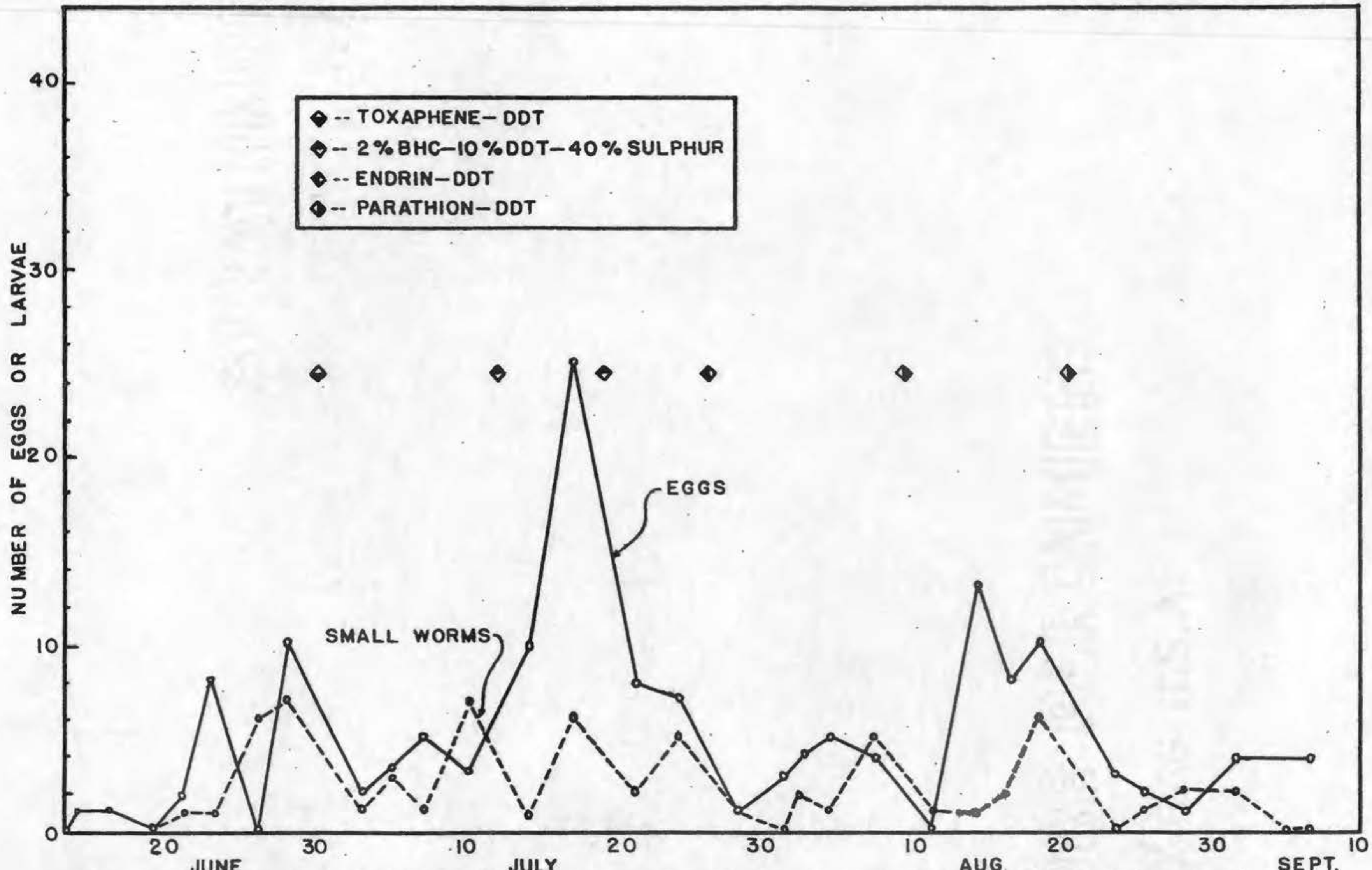

FIG. 4—AVERAGE SMALL BOLLWORM AND EGG COUNT PER 100 PLANTS (DAN BRIJALBA FARM, 1956)

period of time. As the worms became older, they moved down the plants boring into larger bolls. These older larvae were usually never present on the upper portion of the plants where small larvae were found.

When the young worms entered the flower buds, the involucre flared open and the young bud or young boll finally dropped from the plant. This condition is referred to as "shedding" but was not caused by the bollworm alone in the Pecos area. Other insects such as lygus bugs and fleahoppers were concerned in this damage. A large amount of damage was done by the bollworm in this way, as a single larve traveled from bud to bud, deserting each before it fell from the plant.

Cabbage Looper

For several years the cotton growers of the upper Pecos Valley had not considered the cabbage looper a major pest of cotton. Usually they appeared in small numbers late in the summer and were easily controlled. Some cotton growers believe this pest is more beneficial than harmful when they occur in small numbers. They think that a small amount of injury will cause the plants to slow down vegetative growth temporarily and produce fruit more rapidly.

In the summer of 1955, an unusual outbreak of cabbage loopers occurred in the Pecos area. Tremendous numbers of looper moths began to migrate into the cotton fields. It is presumed that they migrated from the Rio Grande Valley. They were reported near Bakersfield, 90 miles southeast of Pecos, on July 22 and reached the Pecos area July 26, 1955.

These looper moths are crepuscular, being most active at night but also very active during cloudy days. Generally, they are inactive during the daytime. However, they managed to lay enormous numbers of small disc-shaped eggs in spots scattered throughout the fields. These eggs were crystal white in color and approximately $1\frac{1}{2}$ times larger than the bollworm eggs. As they became older a small larva could be seen developing inside each egg shell. This was also true for the developing bollworm but the tiny looper was much more sharply defined beneath its egg shell. The larval head first appeared as a black dot and grew larger as the egg neared the hatching period.

The looper eggs were more numerous near the edges of the fields. They were laid singly on all parts of the plant, but the greatest number were laid on the underside of the lower leaves. No major correlation between the looper egg population and irrigation dates could be established because they occurred in large numbers both on dry cotton and on freshly irrigated cotton.

The 1955 looper egg infestation coming as an aftermath of the moth flight showed one definite peak with the largest number found on August 10, as typically seen on the James Moore farm (Fig. 5). Many of the eggs survived natural control factors, and chemical treatment had to be recommended soon after egg hatch. At Pecos this began 5 to 8 days after deposition, depending on the local weather conditions.

After hatching, the larvae started feeding on the leaf tissues on the underside of the leaves. The small loopers were very active and fed rapidly on all leaves of the plants. The larvae crawled from leaf to leaf in a looping motion. When being disturbed they had the habit of raising upon their prolegs or curling up and dropping to the ground. In heavily infested spots in the field the cotton foliage was left in a very ragged looking condition.

When the feeding period of approximately 18 days had been completed, the larva spun a white cocoon and transformed into a pupa. The newly formed pupa was light green in color and could easily be seen inside the cocoon. The pupa turned brown just before the moth emerged. It was usually attached to the underside of the leaves. Sometimes the larva pulled the edges of the cotton leaf inward, thus forming an enclosure around the cocoon.

During 1956, the cabbage looper moths appeared in the Pecos area on June 23, as compared with July 21, 1955. It has been suggested that this early appearance might be due to the fact that abnormally warm temperatures in 1955 and 1956 permitted loopers to overwinter in the Pecos area. An alternate explanation proposed is that abnormally dry conditions in southern Texas and Mexico in 1956 may have deteriorated host plants earlier than usual, thus causing an early migration to irrigated fields in the Pecos area.

Looper eggs were very numerous with 200-300 eggs per hundred plants being observed in some areas. The largest egg infestation was reported on July 25, 1956. Figure 6 shows a typical situation. The egg population fluctuated somewhat, but a continuously high infestation prevailed from July 18 to September 1, 1956. Many of these eggs were destroyed by natural conditions. Some were observed being fed upon by ground beetles. A great number were destroyed by large looper larvae as they fed upon the leaves and accidently devoured the eggs. This was due to an overlapping of generations that occurred in 1956.

The loopers first appeared while the cotton was very small. In some instances they fed upon the whole plant and left only the stalk

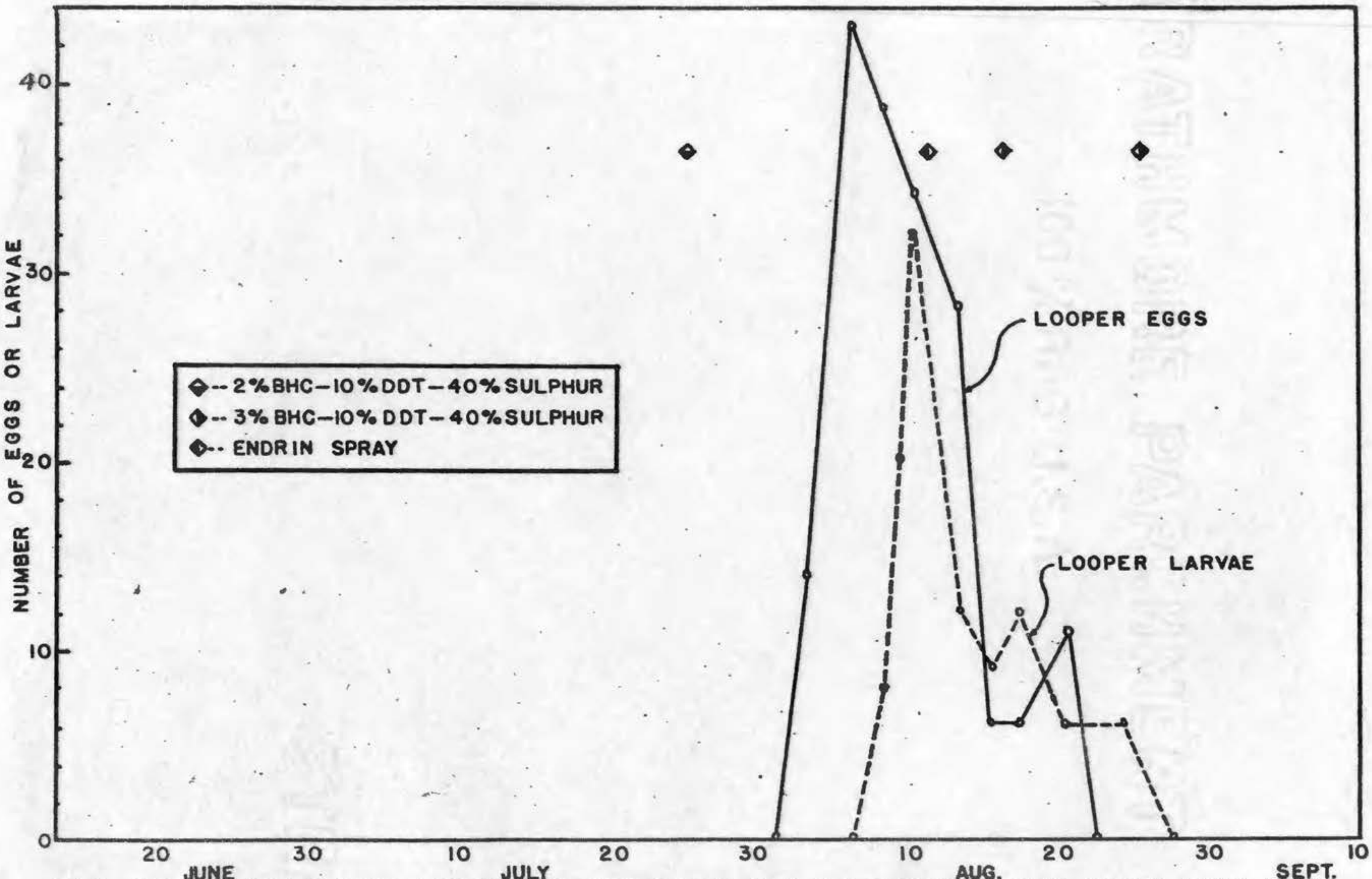

FIG.5—AVG. CABBAGE LOOPER LARVAE AND EGG COUNT PER 100 PLANTS (JAMES MOORE FARM, 1955)

and stem standing. As in 1955, when the plants became more mature, the outer edges of the older leaves seemed to be preferred by the loopers. They usually started feeding between the midrib and the outer edge of the leaf. In heavier damaged areas, they completely consumed all parts of the leaves leaving the older and coarser veins only. When heavily damaged by loopers, the cotton looked stunted and shed fruit very heavily. Under such conditions chemical control and an abundance of water were recommended. If the population was reduced considerably the plants in most cases revived quickly when water was applied immediately. The cotton produced new leaves at the top of the plants and started growing more rapidly.

Looper damaged plants occurred in all the fields under observation. In some fields the injury was very slight, but it was heavy in many cases. An estimate of the loss was made by S. L. Lane, a farmer in this area. He concluded the cabbage looper was responsible in increasing his insect control cost from $18 to $35 per acre and decreased production approximately one-half bale per acre. This was a severe case, but many acres of cotton showed heavy damage in 1956.

Cotton Fleahopper

The cotton fleahopper was the most injurious pest on cotton during June, 1955, in the Pecos Valley. Fleahopper adults were first observed June 13, 1955. The population varied through the Pecos area, ranging upward to 75 insects per 100 terminals. The adults had a habit of flying when disturbed and were very hard to accurately count. In flight they appeared as a small piece of cotton floating through the air above the plants. They were more numerous on the older cotton

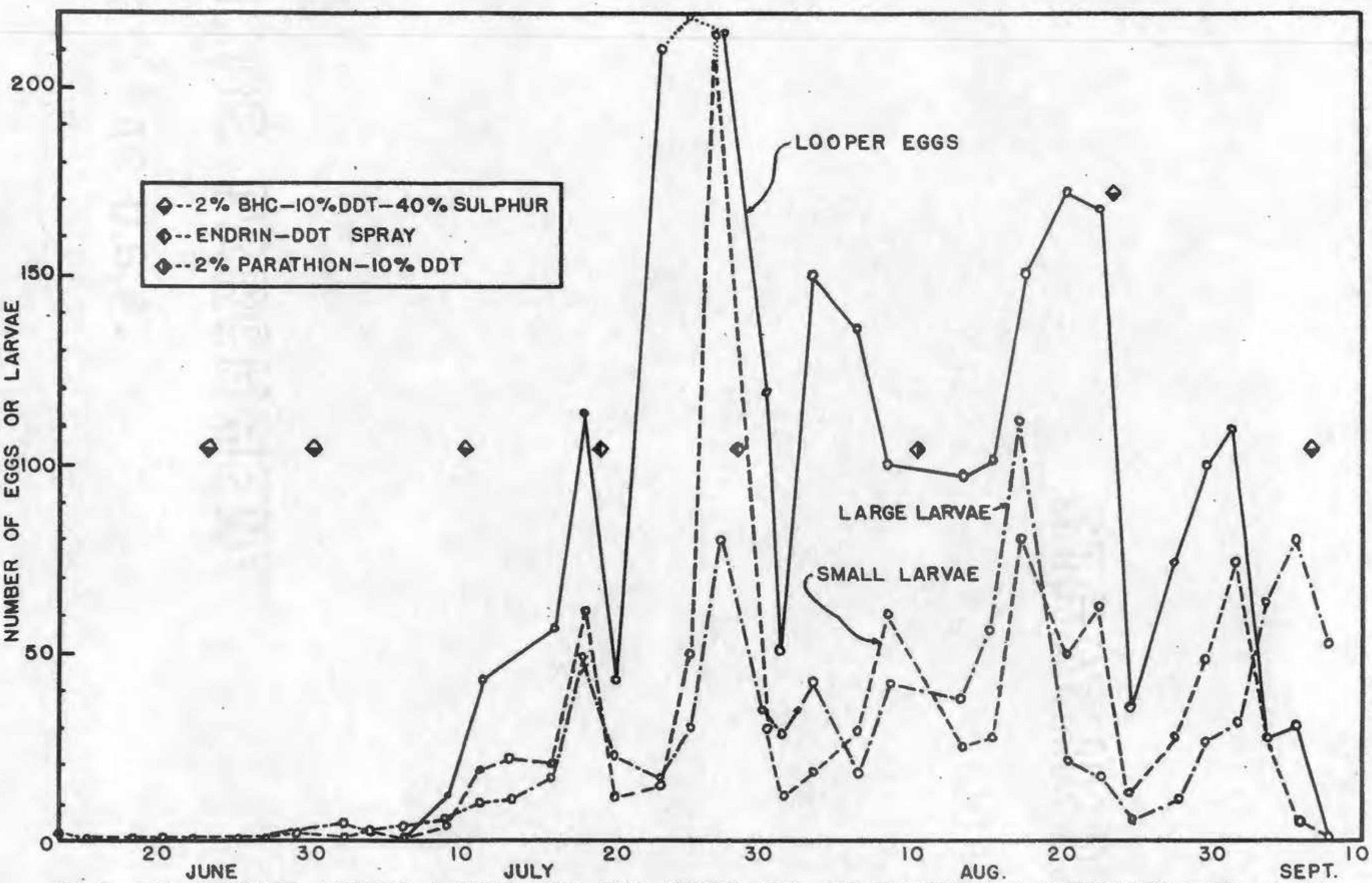

FIG. 6—AVG. CABBAGE LOOPER LARVAE AND EGG COUNT PER 100 PLANTS (T.R. CHENOWETH FARM, 1956)

which showed good growth and some fruit present. Fleahoppers were found on both dry and freshly irrigated cotton. If excessive dryness was permitted and wilting occurred, the fleahopper usually migrated into more favorable areas.

The adults were present about six days before their numerous small greenish nymphs began to show up throughout the area. The greatest number were found June 22, 1955. Three population increases were observed with the first occurring in June and the other two in July. The infestation record on the Don Roberson farm (Figure 7) was a typical example. The effect of chemical control is shown in this figure. No fleahoppers were found after July 25, 1955.

At Pecos, most of the fleahoppers were observed feeding on the upper portion of the cotton plants. The favorite portion of the plant was the new terminal growth and very small squares. The nymphs and adults both fed on the cotton plant causing severe damage to the squares about the size of a pin head. The injured squares turned brown or black and soon dropped from the plant. These insects also fed on other parts of the cotton plants where they caused swellings to occur. These lesions frequently were present, but very little damage could be correlated with this injury.

The reduction in yield by fleahopper damage in the Pecos Valley is very debatable. They usually damaged only the first or bottom crop. The fleahoppers did very little damage to the mid and late season fruit. After heavy fleahopper damage occurred it took approximately ten days for the plants to recover and produce a noticeable number of squares. When fleahoppers were chemically controlled early

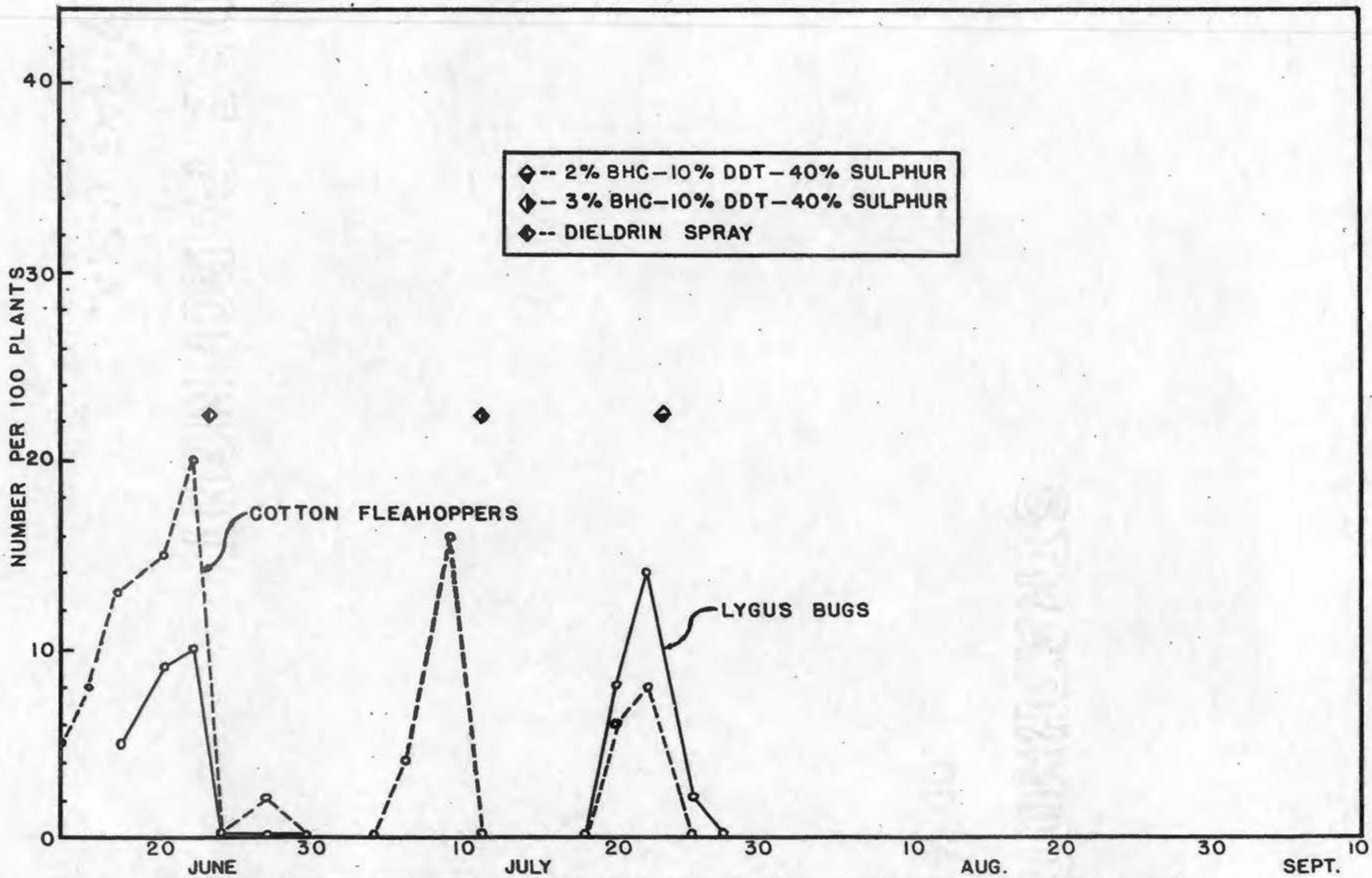

FIG. 7 — AVG. LYGUS AND FLEAHOPPER COUNTS PER 100 PLANTS (DON ROBERSON FARM, 1955)

in the season, the cotton produced a crop much earlier than the untreated fields. In 1956, the fleahopper population was very low and did very little damage to the cotton crop.

Lygus Bugs

The three most common species of lygus bugs, according to New Mexico Agriculture Experiment Station in 1952, in the lower Rio Grande and Pecos Valleys include the following: the tarnished plant bug, *Lygus lineolaris* (P de B), the legume bug, *L. hesperus* (Knight), the pale legume bug, *L. elisis* (Van D.). All three of the above species were observed in the Pecos area. In 1955, the tarnished plant bug was the most numerous species present when adjacent alfalfa fields were cut. In cotton fields of the Pecos Valley these lygus bugs lived up to their reputation as major cotton pests during one of the two years of this study. However, in preceding years they were also found to be a serious pest of cotton.

Both the lygus nymphs and adults injure the cotton crop. This insect feeds mostly on squares and small bolls. It causes them to fall from the plant or remain on it and develop into deformed flowers and bolls. This injury produces an increase in growth of leaves and stems. At Pecos, the injury also caused a loss of quality by the presence of damaged fiber or lint. Many of the seeds turned black after lygus fed on the small bolls. On older bolls, feeding resulted in cell deterioration which causes a scar-like tissue to form. This condition caused the lint to cling to the burs.

On many alfalfa fields the lygus bugs caused a dwarfing of the plants. This condition did not occur on cotton. Very little damage to the vegetative growth of the cotton plant could be attributed to them. This was probably due to the rapid growth of the cotton plants in this area.

In July, 1955, a 175-acre field was found to have 50 percent of its fruit damaged by lygus bugs. They were first observed on June 17 and reached their population peak on July 22 (Figure 7). This generation of lygus was mostly adults and they are believed to have migrated from adjacent alfalfa fields since several acres had just been cut in this area.

The adult bugs were found flying from plant to plant, being most active during the cooler portions of the day. During the hot part of the day they had the habit of grouping themselves on the underside of the leaves or on other parts of the plants away from the sun. They were attracted to vigorous growing cotton with lots of fruit present. The lygus bugs in the Pecos area built up populations on alfalfa which moved to cotton after each cutting. Consequently the infestation on cotton was greatly influenced by the amount of land planted to alfalfa and its distance from the cotton fields.

Sweepings were made in alfalfa on March 22, 1956. A small number of lygus adults were present on the alfalfa at that time. In the cotton fields lygus bugs were present in varying numbers from June 11 to August 6, 1956, but were never a serious pest.

The overall lygus damage to the cotton yield is uncertain in this area. If other pests have reduced the fruiting potential of the plant then lygus bug injury would become more important.

Thrips

The species most common in the Pecos Valley was collected by the author and identified by Miss Kellie O'Neil of the United States National Museum as Frankliniella occidentalis (Perg.). This species is variously known as western flower thrips, western thrips and grass thrips (Smith 1942). According to Watts (1936) 11 species of thrips have been found on cotton. None of these species were collected in the Pecos Valley.

The western flower thrips was a common pest of cotton in the Pecos Valley. Thrips were observed in varying numbers throughout the inspection periods of 1955 and 1956. They were first found on the leaves and new terminal growth present in the early part of June. Most of their damage was done during this seedling stage but they were found in larger numbers on more rank cotton during July and August.

The first evidence of thrips injury on seedling cotton was a grayish color found on the underside of the leaves. This color was due to the destruction of tissues usually along the leaf veins. Later stages of the injury could be recognized by the puckering of the leaves. The heavily damaged leaves formed a cup-like shape with the outer edges turning up. Usually these outer edges would roll or become ragged. This damage was closely associated with aphid damage which, however, caused the leaves to become umbrella-shaped. Excessive thrips injury caused an early dwarfing of the plants. The cotton outgrew this injury very quickly and little effect on the total yield could be correlated with thrips damage.

A very heavy thrips infestation was observed in blooms and on leaves during July and August of 1956. These thrips were present in large numbers and had an irritating bite when disturbed. The amount of damage to the blooms was never determined. It is believed the damage they did, at this particular time, was very minor and no control measures were recommended specifically for thrips.

METHODS OF APPLICATION

In the Pecos area insecticides in the form of dusts or sprays were applied by aerial and ground equipment. The rank growth and size of the plant, in July and August, and wet ground make it almost essential to use aerial applications. Two types of airplanes were used for application purposes. The L-4 cub and the Stearman biplane were most commonly used. Airplane sprayers consisted of a steel tubing called the spray boom suspended beneath the wings. The boom was divided into two parts by the pump and the fuselage. When spraying "solid"[1] cotton the boom was fitted with nozzles spaced roughly every 4 to 5 inches. Where four rows of cotton were planted and the width of 2 or 4 left idle, the middle nozzles were removed. The airplane dusters consisted of a hopper inserted in the front cockpit, a wind driven agitator, a feed-control gate, and a venturi spreader. The aerial application equipment will not be discussed in detail because of the many different types of sprayers and dusters used.

Aerial applications of chemicals were used extensively during 1955 and 1956. Independent aerial applicators were located throughout the Pecos area. They applied the poison in the form of dust at the rate of 3 cents per pound. Spray was usually applied at $1.00 per acre of cotton poisoned. These prices included the handling and

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[1]No rows left unplanted

transportation cost to and from the fields. The above prices were common, for the two years when applying chemicals to "solid" cotton. In 1956, the application prices increased. Many farmers planted 2 or 4 rows of cotton and left the width of four rows idle. They did this to give the cotton plants more room in sending out new branches, therefore increasing the amount of fruit per plant. This type of farming brought about a different insecticide application program. They planned to use this dry idle strip between the cotton for the tractor and ground equipment to operate. Farmers that planted their cotton in this manner thought it would be more economical to use ground equipment since by this method it would eliminate applying insecticides to blank rows.

Types of ground insecticide applicators varied greatly and usually were of the same brand as the farming equipment on the individual farms. The most common ground machines used were tractor-drawn dusters. Very few acres were poisoned by ground spray machines and they will not be discussed. The duster is usually operated from the tractor power take-off. The nozzles on the boom were placed at a level as close to the plants as possible in order to minimize drift of the dust. A cloth canopy or tarpaulin was usually attached to the boom to reduce the amount of poison lost by drift.

The use of ground machines proved very satisfactory for early season insect control. The amount of insecticide used per application was reduced approximately one-third lower than the amount applied by aerial means. However, when using ground machines, farmers had to poison when the ground was dry, instead of waiting until the insect infestation warranted control. This plan worked fine until the water backed up into the cotton rows and made turning of ground equipment very difficult. In some cases, this "tail" water made it impossible to use ground equipment. This usually resulted in more total applications applied per season unless good management of the irrigation water was used.

Dusting

As previously stated, insecticides in the Pecos area were applied in the form of dust or spray mixtures. Many of these farmers requested the use of dust on their cotton because of past performances of dust in this area. Dust applications, throughout the season, usually proved very satisfactory because of better coverage on rank cotton. In 1955, approximately 90 percent of the chemicals applied were in the form of dust mixtures. These mixtures were applied during the early morning hours when the air was calm. It was necessary, in getting effective control, for the dust to stay down among the plants and not rise and float away. During July and August the presence of dew on the cotton plants was very common. Dew was not a necessity for control, but a much better adherence and coverage usually occurred.

A decrease in the amount of dust used occurred in 1956. Some dust mixtures were used for early season control, but poor results occurred in many parts of the Pecos area. When this condition showed up, we recommended the use of sprays and better control was obtained. It is believed that the poor controls from dust applications were due to the low humidity and high temperatures present in 1956. Practically no dew was found on the cotton leaves and the dust particles failed to stick to the plants for more than a short period of time.

The dust combinations were usually mixed and bagged at a chemical plant and were delivered ready for use. Only one dust mixing plant was located in Pecos and most of the dust mixtures were shipped in from other parts of the country. The organic insecticides in dust mixtures usually contained the toxicant along with carriers such as talc, pyrophyllite, or in mixtures with other insecticides.

Application rates of dusts varied throughout the season. The amount of dust recommended depended primarily on the size of the cotton plants and the amount of technical poison per pound of dust. Also, the application rates increased if such insects as the bollworm larvae were large in size because large larvae were not killed by smaller dosages. The amount of dust varied from 10 to 20 pounds per acre.

Spraying

In July and August, usually spray mixtures were used on a small scale because of the rank growth of cotton. In 1955, about the only spray used was applied in early June to control the fleahoppers and lygus bugs. The cotton was small at this time, and a good coverage was obtained from sprays. Spray recommendations were made because of their longer residual action, being effective 3 or 4 days longer than dusts. The period of effectiveness of sprays approximated two weeks.

Several organic insecticides, applied in spray form, were used widely during 1956. Results during the past year indicated that concentrated sprays of organic insecticides applied by aircraft or ground equipment, gave control of cotton insects equal to and sometimes better than with dusts. Sprays had a wide range of usage in that they could be applied during most of the day-light hours even under conditions of relatively strong winds. They were at an important disadvantage when heavy dews occurred because of the large amount of run-off from the plants. Sprays were successfully applied to cotton for control of all the insects found, except the cabbage looper. However, despite relatively poor looper control, the spray mixtures proved much better against this pest than dust mixtures using the same amount of actual toxicant per acre.

The application rates of sprays varied throughout the season because of the different growths of the cotton plant. When the cotton plant was small only a small amount of spray mixture was used. After the plants became older and more rank the application rates were increased. For airplane spray applications, it was suggested that from 3 to 5 gallons of spray containing the recommended rate of toxicant be applied per acre. It was essential to use some method of flagging or marking of the swath for airplane spraying. When using ground rigs, from 5 to 8 gallons of spray containing the recommended rate of toxicant were applied per acre.

GENERAL CONTROL OF MAJOR PESTS

The chemical control recommendations given farmers in the Pecos area, usually were those tested and approved by the Department of Entomology at Texas Agricultural and Mechanical College. Usually 5 to 7 chemical applications were necessary for insect control during the period of June to September of each year. Occasionally, fewer applications were needed, but in some cases several more were needed. Repeat applications were necessary and were recommended if the poison was washed off the plants within 20 to 24 hours after application. However, in some cases a light shower was found to "reactivate" DDT mixtures after they had been on the plants for 5 to 6 days. At least there was a sudden and otherwise unexplainable decrease in number of stages present and a reduction of infestation. This reduction did not occur in untreated fields.

Early Season Control

In this study, the writer considers chemical and biological control of cotton insects, during June, as early season control. Early season chemical control was very unpopular in this area due to the early infestation of bollworms showing up in mid-June. Many Pecos farmers say, "When you start poisoning you have to keep it up throughout the rest of the season". This statement proved very true because of the mortality of beneficial insects recorded after chemical applications. The beneficial insects usually held the bollworms in check in watered fields during June.

The actual value of beneficial insects, in the Pecos area, was not accurately determined. As previously stated, on June 12, 1955, one Pecos farmer bought several thousand lady beetles (species unknown) and put them in his cotton field. Either as a result of this, or the action of local predators, or parasites, or to other unknown factors, the bollworm infestation remained low in this field until June 26, 1955. A heavy infestation of lygus bugs and fleahoppers showed up at this time, and chemical control had to be recommended. This farmer wanted to save his lady beetles and at the same time control the lygus and fleahoppers. It was recommended that he use a weak spray solution containing 0.124 pounds of dieldrin emulsifiable concentrate and 3 gallons of water per acre. Following this application there was approximately 90 percent reduction of the lygus and fleahoppers infestation. Very few beneficial insects were found after this dieldrin application, except in the case of lady beetles. In other fields, where DDT was used in the control mixture, very few beneficial insects of any type were present after chemical application. In contrast to this throughout the Pecos area, in 1955, it was observed that dieldrin depressed the lady beetle population less than any other chemical mixture used except when it was applied at 0.2 pound or more per acre. Dieldrin was found by Campbell and Hutchins (1952) to be less toxic to *Hippodamia convergens* than either DDT or Toxophene.

Approximately 20 percent of the total contracted acres, in 1955, warranted early season chemical control. The insects most numerous at this time were the lygus bugs and fleahoppers. However, in some areas, thrips occurred in large numbers. The most common insecticide used in controlling the lygus, thrips and fleahoppers was 1 pint of dieldrin emulsifiable concentrate containing 0.187 pound of actual dieldrin per acre. If several bollworm eggs or moths were present at this time, two-thirds of a gallon of BHC-DDT (0.6lb-1.0lb) mixture was recommended. The BHC-DDT mixture was recommended because dieldrin was relatively ineffective against the bollworm.

Very few harmful insects were present in June, 1956, and early season chemical control was rarely necessary. However, the bollworm infestation showed up very early, but it never increased above approximately 3-5 percent. It was usually held down by predators. In many fields these predators, mostly lady beetles, Hippodamia convergens (Guér) and Olla abdominalis (Say), flower bugs, Orius insidiosus (Say) and O. tristricolor[1] (Say), and collops beetles, Collops quadrimaculatus (Fab), were present in large numbers. Unless the predators were killed by poison the use of chemical control throughout the month of June was not necessary in many instances. When chemical control was necessary, we recommended the BHC-DDT mixture as previously mentioned, because of the effective results obtained in controlling the bollworms with this mixture. Usually only one early season control application was needed.

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[1]Orius tristicolor (Say) is considered a variety of O. insidiosus (Say) by some authorities.

Mid and Late Season Control

The control of harmful pests of cotton during July and August, in the Pecos area, was usually a continuous program. The cotton bollworm and the cabbage looper were the most injurious pests of cotton at this time. Most of our control recommendations were aimed at controlling these two species. When giving recommendations the possible effects of treatments on all harmful insects were considered. This made it necessary to control as many harmful insects as possible with one application.

The principal chemical used was DDT. It was found that DDT, at different amounts, would effectively control the bollworm which was the major pest found in this area. Past experience had shown conclusively that the use of DDT alone for bollworm control greatly increased the possibility of injurious aphid, thrips and spider mite infestations. This condition developed because the DDT killed the parasites and predators that tended to keep these insects under control.

With the previous problem in mind the writer, during the season of 1955, usually recommended and obtained effective control with a dust mixture containing 2 percent BHC, 10 percent DDT, and 40 percent sulphur. The amount applied per acre ranged from 15 to 20 pounds depending on the size of the plants and the severity of infestation. The presence of BHC in the mixture helped to control aphids and thrips and was very effective against the cotton leafworm. When the aphid infestation was very heavy, the amount of BHC in this mixture was increased from the usual 2 percent to 3 percent. If excessive numbers and much damage were present, a 2 percent parathion and 10 percent DDT mixture at 15 pounds per acre was found more effective. Sulphur was added to this mixture because of its miticidal effects. Sometimes the spider mites increased even though the sulphur was added to the mixture. When heavy infestations of spider mites were present, we found 0.25 pound of systox emulsifiable concentrate per acre to be most effective.

Prior to 1955 cotton growers in this area seldom if ever, treated for loopers because they usually occurred late in the season after most of the fruit was mature. When damage increased in 1955 looper control was recommended. The most effective looper poison in 1955 was a spray mixture of 0.25 lb. methyl parathion plus 0.4 lb. endrin per acre. However, this mixture did not control the bollworms. When bollworms were present a spray of 0.4 pound endrin plus 1.0 pound DDT was recommended and a satisfactory control was found. Dust mixtures containing the same amount of toxicants did not give an effective control of cabbage loopers. In almost every case a build-up of thrips and aphids occurred following an endrin-DDT application.

On August 9, 1955, a looper disease showed up and completely controlled the loopers in some fields thus reducing the need for chemical control. Semel (1956) found a disease of loopers on crucifers in New York and described it as a polyhedral wilt disease. The characteristics he mentioned corresponded closely with those found on loopers in cotton fields during 1955 in the Pecos area. The infected loopers first became sluggish in their movements and later became inactive and died. During this time the body coloration changed from a green to a pale yellow or brownish color. Deterioration of the internal tissues took place giving the body a fluid consistency. Usually the looper turned loose of the plant with its rear legs and hung limp from the plant by means of its true legs. Soon the body turned brown to blackish, the skin usually ruptured and the body contents, which had liquefied and darkened usually scattered over the plant tissues. If sufficient moisture and high humidity conditions were present this disease spread rapidly from field to field.

In 1956, the same control program as used in 1955 was started. However, the dust mixtures, used in controlling the bollworm, became ineffective probably due to high temperatures and low humidity conditions (Table 1). When this happened, a spray mixture containing 0.125 pound parathion and 2.0 pounds DDT per acre gave good control of all harmful insects present except the cabbage looper. Also, a spray mixture containing 0.6 pound BHC and 1.0 pound DDT proved very effective against the bollworms and aphids. This mixture did not control a heavy thrips infestation and the previously mentioned parathion-DDT spray was used. In early August, dews begin to appear because of the high moisture content in the air plus favorable temperature conditions and the dust mixtures containing 0.45 pound BHC, 1.5 pounds DDT, and 6.0 pounds sulphur were again very effective in controlling every insect present except the cabbage looper.

The cabbage looper in 1956 proved to be a real problem. Effective control could not be obtained with any of the available chlorinated hydrocarbons or organic phosphates. The spray mixtures of 0.25 pound of methyl parathion and 0.4 pound of endrin per acre were still the most effective, but heavy looper damage still showed up throughout the area. Bollworm infestations forced the mixing of DDT with the endrin. Two and sometimes three applications of 0.4 lb. of endrin and 1.0 pound of DDT per acre were applied to control the loopers in late July and early August.

One Pecos farmer applied 20 pounds of 2 percent BHC, 10 percent DDT, and 40 percent sulphur dust on July 25; 0.25 pound of parathion and 0.4 pound of endrin spray on July 30; and 20 pounds of 3 percent BHC, 10 percent DDT, and 40 percent sulphur dust on August 3, per acre, before getting effective looper control. The looper disease showed up, during this time, and helped to control the loopers in this field. While looper disease showed up in spots, its over-all benefit, in 1956, throughout the Pecos area, was much less than in 1955. It is believed that the dry weather occurring at this time reduced the spread of the disease.

SMALL PLOT LOOPER CONTROL TESTS

Polyhedral Disease Experiment

On August 2, 1955, an attempt was made to inoculate healthy loopers with the previously described polyhedral disease. Two loopers known to have this disease were put in one gallon of water. The body contents liquefied and mostly dissolved in the water. This mixture was put in an ordinary hand fly sprayer and thoroughly applied to 10 plants. These plants were located in a field that was assumed to be free of this disease and had not recently been poisoned. Two loopers of the same size or instar were put on each of these 10 plants. These loopers were selected from a field where no disease had previously been recorded. They were inspected each day until all had died from the disease or had pupated.

The reaction of the loopers to the spray was very interesting (Table 5). The first two days following spray application, the loopers fed freely on the cotton leaves and showed no external symptoms of the disease. Three days after inoculation, one 4th instar looper was sluggish and somewhat inactive but some feeding continued. The following day this larva crawled on top of a cotton leaf and died. Hot weather was present at this time and death usually occurred very quickly after disease symptoms first appeared. Two of the 4th instar and all of the mature larvae pupated. This experiment revealed that the 3rd instar larva probably was most susceptible to the disease.

Table 5 - Effect of artificial dissemination of polyhedral virus on the cabbage looper, Pecos, Texas, 1955.

Date Inspected	Number of Loopers Surviving at Given Dates on Plants Inoculated with Polyhedral virus.[1]				
	1st Instar	2nd Instar	3rd Instar	4th Instar	5&6 Instars
August 3	4	4	4	4	4
" 4	4	4	4	4	4
" 5	4	4	4	3	3 (1)[2]
" 6	4	4	0	2	(4)
" 7	4	0	0	2	(4)
" 8	4	0	0	2	(4)
" 9	1	0	0	(2)	(4)
" 10	0	0	0	(2)	(4)

[1]Plants inoculated and infested August 2, 1955.

[2]Parenthesis indicates successful pupation.

The 1st and 2nd instar stages contracted this disease, but had developed and actually were in the 3rd instar stage when the symptoms showed up. All the looper larvae under observation either showed Polyhedral disease symptoms and died or pupated on the cotton plants. No larvae which were inoculated in the first, second or third instar stages successfully reached the pupal stage.

Insecticide Tests

In early August, 1955, as the looper damage began to show up, several treatments of endrin and other chemicals had to be used as a substitute. Very poor looper control was obtained and the damage kept increasing. With this problem in mind, an experiment was conducted to determine the most effective cabbage looper control.

On August 15, 1955, seven experimental field plots were set up north of Pecos, Texas. The plots were located side by side on the same farm. Each plot was 12 rows wide and 109 feet long (0.1 acre). Infestation counts were taken one day before and three days after treatment. One hundred plants were thoroughly examined in five different places in each plot. The cotton plants in all the plots were practically the same size and the cultural practices used were equal in all plots.

The spray mixtures were applied with a 3-gallon compressed air hand sprayer. The emulsifiable concentrates plus one gallon of water were applied to each spray plot. Different dosages of concentration were obtained by varying the amount of emulsifiable concentrate. Dust mixtures were applied with a rotary hand duster at the rate of 10 pounds per acre.

The over-all results of the cabbage looper experiment, in 1955, were very disappointing. The loopers were about half grown when the insecticides were applied and in most cases a very poor kill was obtained. The kill ranged from 19 to 82 percent (Table 6). A dust mixture containing 0.1 pound of rotenone per acre gave the poorest kill when checked three days after treatment. A spray mixture containing 0.25 pound methyl parathion plus 0.4 pound endrin per acre gave the best results of any insecticide used, namely 82 percent kill. Although the percent larval reduction was relatively low for some of the treatments, the amount of damage in all treated plots was greatly reduced when compared with the check plots. However, effective control could not be obtained with any of the insecticides except endrin. The results of this experiment could not be determined because the looper disease killed several of the loopers a few days after treatment.

The cabbage looper is believed to be resistant to several chlorinated hydrocarbons because of the poor control obtained in 1955. Under ordinary field conditions in 1956, all chemicals used gave very poor results. The insecticides were applied to the same experimental plots on July 21, 1956. A spray mixture containing DDT and endrin was added to the 1956 experiment, because it was used widely to control the bollworm along with the cabbage looper. The chemicals were applied in the same manner as in the 1955 experiment.

Results from the plot experiments in 1956 were very much like those found in the contracted field treatments. All chemicals were less effective than in 1955. The controls in the plots ranged from

Table 6 - Comparative toxicity test of different insecticides to the cabbage looper, Pecos, Texas, 1955.

Toxicant used	Rate per acre	Number Living Loopers One Day Before Treatment	Number Living Loopers Three Days After Treatment	Percent Control
Calcium arsenate	6.0 lbs.*	21	10	52
Rotenone	0.1 lb.*	16	13	19
Nicotine sulphate (40%)	1 pint	20	13	35
3-10-40 mixture	10.0 lbs.	14	8	43
Methyl parathion plus endrin.	0.25 lb.* 0.40 lb.*	29	5	82
Endrin spray	0.40 lb.*	26	5	80
Check	-	21	37	-

*Rates are actual material.

26 to 55 percent (Table 7). Best results were obtained from sprays containing 0.4 pound endrin plus 1.0 pound DDT per acre. The lowest kills were obtained from 0.1 pound of rotenone per acre.

It can be noted in Table 7 that there was a large increase in the check population during the three days after treatment. Accordingly the actual percent kill in treated plots was higher than is shown. However, this latter fact is but of academic interest since the level of control based on the remaining infestation is the true index to continuing plant damage. More effective looper control methods are greatly needed in the Pecos area.

Table 7 - Comparative toxicity test of different insecticides on the cabbage looper, Pecos, Texas, 1956.

Toxicant used	Rate per acre	Number Living Loopers One Day Before Treatment	Number Living Loopers Three Days After Treatment	Percent Control
Calcium arsenate	6.0 lbs.*	152	94	38
Rotenone	0.1 lb.*	89	69	26
Nicotine sulphate (40%)	1 pint	110	76	31
3-10-40 mixture	10.0 lbs.	170	102	40
Methyl parathion plus endrin.	0.25 lb.* 0.40 lb.*	164	79	52
Endrin spray	0.40 lb.*	110	58	47
Endrin and DDT spray.	0.40 lb.* 1.00 lb.*	146	66	55
Check	-	167	219	-

*Actual toxicant.

SUMMARY AND CONCLUSIONS

During the summers of 1955 and 1956 the writer operated the Stanford Entomology Service located at Pecos, Texas. This service consisted of three times a week inspection of the customers' cotton fields for a 13-weeks period for which each farmer paid $1.30 per acre. The total acreage under contract was 2,550 in 1955 and 4,400 in 1956. Infestation counts were made for the following injurious species: the cotton bollworm, cabbage looper, cotton fleahopper, lygus bugs, thrips, stink bugs, leafworms, aphids, and spider mites. These counts were interpreted for each individual field and the owner advised on the insect infestation in his field. If control was needed, recommendations were given.

The cotton bollworm and cabbage looper were found to be the most injurious species on cotton during both years. The bollworm appeared early in June and was a continuous pest throughout the season. Bollworms were more abundant during the latter part of July on rapidly growing cotton. Bollworm moths were found to be very numerous in those parts of the field which had been recently irrigated and were more active during the early morning and late evening hours. The eggs usually hatched in three days after oviposition. Predators, notably, lady beetle larvae and flower bugs, were found to be very beneficial in the destruction of both bollworm and looper eggs.

Great numbers of looper moths appeared in the cotton fields of the Pecos Valley in 1955 and 1956. Serious damage from larval feeding occurred in the first year and increased markedly in 1956. During both years, most looper damage occurred in spots around the edges of the different fields. No major correlation between the looper egg population and irrigation dates could be established because eggs occurred in large numbers both on dry and freshly irrigated cotton.

The cotton fleahopper and lygus bugs were very numerous in 1955 but were never a serious pest of cotton the following year. Lygus bugs were found to migrate from adjacent alfalfa fields after each cutting of hay. They were most active during the cooler part of the day and grouped themselves on the underside of the leaves when temperatures were high.

Thrips were numerous on cotton in 1956 but they caused very little noticeable damage to the cotton plants in the Pecos Area. This was probably due to the fast plant growth seen after and during each irrigation.

Recommendations as to the kind and amount of toxicant, the type of formulation, the method of application and the timing of treatments were based on the injurious and beneficial insects present, weather conditions and the stage of crop development. The most effective early season chemical control of lygus bugs, fleahoppers and thrips was one pint of dieldrin emulsifiable concentrate containing 0.187 pound of actual dieldrin per acre. Information on the control of insects with insecticides was obtained from studies made in 61 fields totaling 6,950 acres that received commercial treatments applied by airplane and ground equipment. Chemical control was also studied in two small plot experiments.

For mid and late season control of all insects except the cabbage looper, the most effective treatments were spray mixtures of parathion-DDT or BHC-DDT and dust mixtures of BHC-DDT-sulphur at different rates per acre. DDT gave the only satisfactory control of bollworms and parathion and methyl parathion were the most effective on aphids. Endrin was moderately effective against the looper but all other toxicants were relatively ineffective.

All insecticides used on the contracted acres reduced the beneficial insect populations somewhat. However, dieldrin depressed the lady beetle population less than any other chemical mixture except when it was applied at 0.2 pound or more per acre. In almost every case a build-up of thrips and aphids occurred following an endrin-DDT application. It was indicated that repeated treatments applied to fields containing bollworms in early season caused the bollworm problem to become more difficult than in similar untreated fields. These developments were thought to be due, at least in part, to the reduction of the predator population.

Dusts were more effective than sprays in the presence of moisture on the plant surfaces and in the absence of wind, particularly in treating rank growing cotton. Dusts were less effective than sprays when applied under dry conditions in the presence of moderate to strong wind velocities.

Ground applicators particularly dusters were more satisfactory than airplanes in early season where conditions permitted their operation. Airplane application was the only feasible method when plant growth was rank and the ground was soft from irrigation water.

This study showed that each year the insect infestations varied in the Pecos area, and the total number of insecticide applications could not be determined in advance. Usually 5 to 7 chemical applications were necessary during the period of June to September of each year. Occassionally, fewer applications were needed, but in some cases several more were needed. Repeat applications were necessary and were recommended if the poison was washed off the plants within 20 to 24 hours after application. However, in some cases a light shower was found to "reactivate" DDT mixtures after they had been on the plants for 5 to 6 days. At least there was a sudden and otherwise unexplainable decrease in number of stages present and a reduction of infestation. This reduction did not occur in untreated fields.

A polyhedral looper disease was found during both years. The disease was sporadic in nature and when weather conditions were favorable it completely eliminated the cabbage looper larvae from the fields. In 1956 this disease was less effective than in 1955, probably because of the low humidity and rainfall conditions. Loopers were inoculated with the virus by feeding on plants sprayed with a suspension of ground up disease larvae in water. All the young larvae and a few of the older ones were killed by the disease. Older larvae contracted the disease quicker, but in some cases pupation occurred before the disease symptoms appeared. The dissemination of this disease might possibly be the answer to an economical control of the cabbage looper in the Pecos Valley. However, much more work concerning the polyhedral disease is needed before any definite conclusion can be made.

The writer suggests that these up-to-date reports of insect abundance and timed control recommendations are the partial answer to a successful overall insect control program in the Pecos Valley.

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