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THE PINK BOLLWORM OF COTTON IN TEXAS

F. A. Fenton and W. L. Owen, Jr.*

FOREWORD

This is a report of a 4-year study, 1928-31 on the pink bollworm in West Texas. It contains basic information on the biology, host plants, dispersal, hibernation and cultural control which the authors distributed in 1932 to a limited number of entomologists.

A considerable expansion is currently being made in the pink bollworm research program of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, and the Texas Agricultural Experiment Station, with the cooperation of several other Southern state stations and the National Cotton Council. Hence, this background information will be valuable to those engaged or interested in the research and control programs for this insect, which has become more serious in the past two seasons.

August 1953

J. C. Gaines, Head
Department of Entomology
Texas Agricultural Experiment Station

The persistence of the infestations of the pink bollworm in certain of the irrigated cotton growing districts in West Texas, the appearance of the insect in several counties in the extreme western edge of the main cotton belt of the State and the need for information which could be used in the prevention of further spread of the pest, resulted in the organization of a cooperative research project between the Texas Agricultural Experiment Station and the U. S. Department of Agriculture. Intensive studies were conducted at Presidio, where the infestation is the heaviest in the State and more extensive ecological data were collected in the more lightly infested districts elsewhere. Data have been obtained on the possible causes of the different degrees of infestation in the several districts where the insect is now present, the possibility of development in host plants other than cotton, the gradual increase of the infestation in the Big Bend district, factors affecting the intensity of infestation in different fields, damage to the crop, biology, natural dispersal, hibernation, survival, the development of the different generations, and the possibility of control by plowing and irrigation, cutting, raking and burning or pasturing. The cooperative project was organized early in 1928 and this report gives a summary of the results of the investigation in Texas to date (1932).

*Respectively, former senior entomologist, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture; and associate entomologist, Department of Entomology, Texas Agricultural Experiment Station.

ECONOMIC HISTORY AND PRESENT STATUS IN TEXAS

East Texas

According to USDA records, the first specimens of the pink bollworm which were found in the United States were discovered September 3, 1917, near Hearne, Texas. Hunter (5) states that during the same year a second infestation was found near Beaumont. Further inspection revealed this second infestation to involve cotton fields in 11 counties in what is called the "Trinity Bay District." These two districts were quarantined to prevent the spread of the pest, which was completely eradicated by field clean-ups and by the maintenance of non-cotton zones. Infestations also were discovered during 1921 in two more localities, near Marilee and near Ennis. The insect also has been completely eradicated from the last two districts so that today, so far as is known, there is no pink bollworm infestation present in Texas east of Midland county.

West Texas

This insect was also introduced into the irrigated cotton growing districts in West Texas and despite non-cotton zones and clean-up campaigns has enlarged its territory. The history and present status of the pest in these more western districts is presented in the following paragraphs:

The Big Bend District. Hunter (5) states that the first pink bollworm infestation was discovered in the Big Bend district in November 1918. In 1919, a non-cotton zone was maintained except at one place and the zone was continued in 1920, during which year there was no outlaw cotton. In 1921, cotton was again planted but infestations were discovered in 12 fields. The district has been maintained as a regulated zone since then, with the exception of 1928, when Brewster county was again made a non-cotton zone. There has been a slow but steady increase in the infestation in this district.

The cotton growing territory in the Big Bend district is located in a narrow valley chiefly along the American side of the Rio Grande in Presidio and Brewster counties. All cotton, which is chiefly of the Acala variety, is grown by means of irrigation, the water being pumped either directly from the river or obtained by means of gravity ditches. The elevation ranges from 3,100 feet above sea level at the upper limits of the valley in Presidio county to 2,100 feet near Castolon in Brewster county. The soils vary from the finest of sands to the heaviest of clays or adobe. Most of the cotton is grown in the lighter sandy or mixed sandy-clay loam soils.

During the period 1928-31, the annual rainfall ranged from 7.50 to 9.95 inches. Beginning with January there was a very rapid rise in the monthly mean temperatures until the peak was reached in June. Following September, there was an equally rapid fall in these. The heaviest rainfall occurred during July and October. During the 4-year period, the maximum temperature recorded was 112° F. in June 1928 and the minimum was 10° F. in December 1929. Temperatures of 100° F. or above were recorded as early as March and as late as October, but occurred frequently from June to September. The mild winter temperature, luxuriant growth of cotton, long growing season and nearness to the heavily infested districts in Mexico are obvious reasons for the heavy infestation of cotton by the pink bollworm in the Big Bend district.

The Pecos Valley. The pink bollworm was discovered in the Pecos Valley of Texas December 21, 1918 according to Hunter (5). Clean-up campaigns were carried out that year and also during the next 2 years. Despite these, however, the infestation has persisted but the insect has never shown any tendency to increase and no damage of importance has occurred. In this valley, cotton is grown by means of irrigation from the Pecos River around Pecos and Barstow, and from natural springs at Balmorhea and Fort Stockton. There also are small districts at Buena Vista, Grand Falls and Imperial which are irrigated from the Pecos River. South and west of Pecos there are a few farms irrigated by means of pumping water from wells. The elevation at Pecos is 2,587 feet, at Balmorhead, 3,225 feet, and at Grand Falls, 2,300 feet. The mean annual rainfall is 10.64 inches at Barstow and 15.13 inches at Fort Stockton. At Barstow, temperatures as low as -4° F. have been recorded, while the absolute maximum is 114° F. Records taken at Balmorhea and Fort Stockton show minimum temperatures of 5 and -7° F. These low winter temperatures are unfavorable for the pink bollworm and probably are the main reason why the infestation in this valley is so light. At present, there is an average of considerably less than 1 percent of the top crop of bolls infested late in the season.

<u>El Paso-Mesilla Valleys</u>. Hunter (5) recorded that the first infestations were discovered in the El Paso Valley November 27, 1920 and in the Mesilla Valley, November 9, 1920. Clean-up work was started, but when it was subsequently found that the infestation was general, this work was discontinued with the exception of the lower end of the valley. The infestation has persisted in the El Paso-Mesilla Valleys and, while there have been years during which more worms were found than in others, the infestation did not show any signs of increasing until 1931, when a general increase was observed, especially in the lower end of the El Paso Valley in Hudspeth county.

Cotton is grown extensively in the El Paso Valley, which extends from El Paso in a southeasterly direction through El Paso and Hudspeth counties. The Mesilla Valley is located mostly in New Mexico, but the extreme southern part lies in El Paso county. As in the other districts mentioned, Acala is the chief variety of cotton grown and, with the exception of the extreme lower part of the El Paso Valley, irrigation water is obtained from gravity ditches from the Rio Grande, the water of which is impounded at the Elephant Butte dam in New Mexico. In the lower part of the valley in Hudspeth county, irrigation water is pumped directly from the Rio Grande. The elevation ranges from 3,450 feet in lower Hudspeth county to 3,690 feet near El Paso. The temperature range for Clint is the El Paso Valley, extends from -1° to 107° F. and the average annual rainfall is 7.66 inches. The luxuriant type of plant growth and summer growing season are both favorable for the development of the pink bollworm in the El Paso Valley but seed sterilization, gin sanitation and low winter temperatures keep the pest in check.

In El Paso county, in the upper part of the valley, the insect, while present in most fields, infests on an average considerably less than 1 percent of the bolls late in the season. In Hudspeth county, in the lower part of the valley, the infestation in some fields is much higher, averaging better than 10 percent of the top crop of bolls. The nearness of cotton in the latter county to that in the Big Bend district offers a good explanation for the heavier infestation present in fields at the lower extremity of the El Paso Valley. Considerable cotton is also raised in the Juarez Valley on the Mexican side of the Rio Grande River. The infestation in cotton fields in El Paso county and in the Juarez Valley is spotted, there being districts on both sides where the infestation appears to be increasing.

<u>The Western Extension</u>. Infested fields were discovered December 31, 1927 in Ector county. Subsequent scouting showed there were six other counties in this district within which had infested fields. This block of seven infested counties was on the extreme western edge of the main cotton belt and so, for the first time, the pink bollworm had appeared beyond the gap of desert country which separated the isolated irrigated valleys from the main cotton belt. No field clean-up was

attempted, but all gins, oil mills and similar places were thoroughly cleaned and most of the seed ginned in this district were sterilized. It was then made a regulated district in which all seed were sterilized at the gins, and the lint compressed and fumigated. Since then, the infestation has apparently died out in all except the two most westerly counties of Ector and Midland where it still persists but does not seem to increase. These counties are a part of the border country between the dry plains of West Texas and the desert. The elevation is 2,779 feet at Midland. The soils are sandy and the rainfall is barely enough to raise cotton without irrigation. There are several varieties of cotton grown but Mebane and Half-and-Half are the most common. The temperature range at Midland extends from -1° to 116° F. The average annual rainfall is 15.91 inches. In the more western counties of this district, low winter temperatures undoubtedly hold the pink bollworm in check. The shorter growing season and especially the stunted determinate growth of cotton are unfavorable for development during the growing season.

HOST PLANTS OTHER THAN COTTON

Okra

Cotton is the principal host plant of the pink bollworm in Texas. The only district where infestation has been found in other malvaceous plants is the Big Bend where okra is quite commonly infested. Experiments and observations show that, under certain conditions, okra is infested in the absence of cotton and that the pink bollworm can overwinter in pods of this plant. Okra is very readily infested near heavily-infested cotton and the species is able to develop at least one generation on okra.

There are three varieties of okra which are commonly planted. These are: a dwarf variety which seldom grows over a foot high and which bears large, angular pods; a tall variety which also produces angular pods; and a tall variety which develops smooth pods. The angular-type pods of the giant and dwarf varieties partly crack open upon maturing, thus enabling the pink bollworm larva or moth to emerge after the pods dry. The smooth-pod variety does not crack open upon drying and, unless the larva cuts a hole while the pod is still soft, the emergence of the moth the following spring would be almost impossible unless the pods were broken open by some agency.

Hibernation experiments carried out during three winters at Presidio proved that, while it is possible for the pink bollworm to survive the winter in okra pods under exceptionally favorable conditions, and pupate and the moths emerge the following spring, this is a rather rare occurrence. These tests are described in the following paragraphs.

In 1927, there was a very heavy pink bollworm infestation in cotton at Castolon in Brewster county. Okra also was infested, although to a lesser extent. February 29, 1928, many okra pods were examined and pink bollworms found alive in them. To determine possible moth emergence from these okra pods, the variety of which was unknown, 183 were gathered and placed in three cages March 20. The soil in the cages was irrigated June 12. No moths emerged from any of the pods in these cages despite the fact that 388 moths emerged from infested cotton bolls in other cages near by.

In the fall of 1928, 10 cages of infested okra pods were installed at Presidio to determine if moth emergence could take place the following spring. The estimated number of live, long-cycle larvae used in the tests was 45 for each of the 4 cages containing the smooth-pod variety and 8 for each of the 6 cages containing the angular-pod variety. There were, therefore, 228 live, long-cycle larvae in cages for a study of the winter survival and moth emergence from okra pods the following spring. In 1929, but one moth emerged from these 10 cages, an average survival of 0.44 percent. This moth emerged April 21 from a cage containing seed capsules of the angular-pod variety.

During the winter of 1929-30, at Presidio, 8 cages of infested okra pods of several varieties were under observation, the estimated number of larvae caged being 112. With this comparatively small number of larvae under test and with the expected high rate of mortality, it was not surprising that no moths emerged the following year.

Observations showed that okra was not infested when allowed to grow in a non-cotton zone the year following a very heavy infestation in cotton in the same district. In 1928, a non-cotton zone was enforced at Castolon but some okra was planted and some volunteered. The plants were watched for the appearance of an infestation. Examinations were made of 25 okra pods on each of the following dates: July 24, August 7, 23 and September 6. Six pods also were picked and examined September 20. No pink bollworm infestation was found in these pods. Although no cotton was planted at Castolon in 1928, there was a scattered growth of volunteer cotton. This was not destroyed until after the plants had developed squares, blooms and young bolls. June 9, 250 squares were examined and an infestation of 44.4 percent was found. This showed that long-cycle moths were present in large numbers at Castolon that year. While this okra was not infested in the absence of cotton, evidence was obtained in the trap-planting experiments of 1931, which proved that this can occur under certain conditions. That year, one pod was found infested out of 496 which were examined from August 20 to November 25. This trap plot was approximately $21\frac{1}{2}$ miles air line from the nearest heavily infested cotton.

It also was demonstrated that once an infestation is developed in okra, the moths emerging from the pods can deposit fertile eggs on okra and long-cycle larvae develop. During August and September 1929, several field cages were placed over growing okra plants. Pink bollworm moths, which had transformed from larvae obtained from infested cotton bolls, were then introduced into these cages. No eggs were found on the okra pods in subsequent examinations due largely to the sticky, abundant pubescence characteristic of the green okra pod. However, exit holes were found in the pods 22 days after the moths had been introduced into the cages and one pupa was discovered in the surface trash. Several moths emerged in the cages 10 days later. September 18, these moths, which had transformed from larvae developed in okra pods, were introduced into another cage likewise set up over growing okra plants. October 15, exit holes were found in the okra pods in the latter cage. No moths emerged from these pods, however, as it was late in the season and the larvae were probably of the long-cycle type.

Other Malvaceous Plants

At Castolon, an experimental planting of Thurberia thespesioides became infested near very heavily-infested cotton during 1927. Later records at Presidio showed that this plant was not infested near a moderate infestation of cotton. Attempts to overwinter the pink bollworm in bolls from this plant were unsuccessful.

At Presidio in 1928, an experimental garden was set aside for a study of other possible malvaceous host plants. Ten of these plants fruited. They were: Abutilon incanum (Link.), butilon sp., Sida physocalyx Gray, Disella hederacea Greene, Disella sagittaefolia Greene, Hibiscus africanus, hollyhock and Sphaeralcea cuspidata Gray. The seed pods of these plants were examined from time to time. One pink bollworm was found in a hollyhock bloom. All of these species were planted along with cotton, which was quite heavily infested, but with the above mentioned exception of hollyhock, none became infested.

HISTORY OF THE INFESTATION IN THE BIG BEND DISTRICT

In 1921, cotton was again planted in the Big Bend district following a 2-year non-cotton zone. Records furnished by the Bureau of Plant Quarantine show that in nine fields examined from October 6 to November 22, the average infestation ranged from 1.7 to 100 percent. From this period to 1928, infestation records were made yearly, first by the Federal Horticultural Board, then by the Bureau of Plant Quarantine. From 1928 to date, these records have been taken jointly by the Bureau of Entomology, U. S. Department of Agriculture and the Division of Entomology, Texas Agricultural Experiment Station. Beginning with 1928, periodic visits were made to selected cotton fields in the district and a seasonal record kept of the progress of the infestation. It is, therefore, possible to compare the infestation from 1928 to 1931.

Square Infestation

Weekly records were taken of the percentage of square infestation from 1928 to 1930, Table 1. These show that the average infestation increased yearly. At no point, however, taking the average for the district as a whole, was there any damage caused by the pink bollworm because of square infestation. In 1928, an average of less than 1 percent of the squares was infested until the week of October 11-16, while in the following 2 years approximately 1 percent was infested the week of September 6-14. The greatest average square infestation was 8.07 percent in 1928, 9.86 percent in 1929 and 22.11 percent in 1930.

Table 1. Average percent of boll and square infestation caused by the pink bollworm, Presidio Valley, 1928-31

Date[1]	Average percent square infestation			Average percent boll infestation			
	1928	1929	1930	1928	1929	1930	1931
June 8-14	0						
June 15-21	0	0.17	0.06				
June 22-30	0.29	0.21	0.55				
June 29-July 3		0.04	0.61				
July 1-10	0.043	0.04	0.12				
July 8-18	0	0.02	0.04				1.50
July 15-25	0	0.02	0.06			2.12	2.12
July 21-31	0	0.03	0.04	0		2.80	1.86
Aug. 1-8	0.033	0.009	0.05	0	3.6	3.10	1.72
Aug. 8-15	0	0.01	0.02	0	2.19	4.12	3.35
Aug. 15-23	0	0.008	0.07	0	3.58	3.22	4.83
Aug. 22-31	0.17	0.38	0.17	0.13	7.04	8.22	12.16
Aug. 29-Sept. 7	0.06	0.58	0.81	0.27	20.55	12.91	17.55
Sept. 6-14	0.1	1.18	1.34	4.08	22.57	19.73	21.90
Sept. 13-21	0.2	0.22	2.19	7.30	22.78	27.55	31.22
Sept. 20-30	0.08	2.98	2.20	10.10	33.70	32.73	45.63
Sept. 27-Oct. 3		3.88	3.50		51.70	35.86	51.67
Oct. 1-10	0.49	4.86	3.41	19.27	44.22	31.50	71.80
Oct. 11-16	1.47	9.37	12.33	30.73	69.83	47.78	73.17
Oct. 15-23	3.95	9.86	17.79	43.55	50.90	62.50	84.60
Oct. 22-31	4.77	9.20	22.11	52.63	60.04	72.86	78.52
Nov. 1-7	5.07	6.89	18.74	60.00		72.32	80.90
Nov. 8-14	6.15	8.91	11.32	60.52	63.38	75.80	77.59
Nov. 15-21	8.07		19.80	76.33		77.57	

1/ Infestation records were taken weekly. The exact dates of each week varied in the different years; hence, the apparent overlapping of some of the dates in this and some of the following tables.

Boll Infestation

When bolls were full grown, counts were made weekly to determine the percentage of boll infestation. These records have been made for the period, 1928-31, Table 2. The percentage of boll infestation increased from year to year. In 1928, an average of less than 1 percent of the bolls was infested until the week of September 6-14 but, during the following 3 years, the first bolls collected showed the district average to be better than 1 percent at the very start of boll maturity. The greatest average boll infestation was 76.33 percent in 1928, 63.38 percent in 1929, 77.57 percent in 1930 and 84.60 percent in 1931. These figures show very little difference in the final peak averages during the first 3 years, although the seasonal infestation was much the lowest in 1928. In 1929 and 1930, there was very little difference in the infestation of the district from week to week, such fluctuations as recorded being due to the impossibility of including all fields in each week's records. Beginning with the middle of October, however, the 1930 infestation was the greater of the two. The boll infestation was especially high in 1931 in the vicinity of Presidio, where many fields were 100 percent infested during October and November.

Unless fungus or bacterial diseases follow the ingress of the larva in a boll, 1 or even 2 larvae may cause very little damage, except in cases where infestation is heavy and green bolls are scarce. When bolls not fully grown are infested, then 1 or 2 larvae may completely ruin the boll. On the other hand, a larger number of larvae will invariably cause serious damage. Therefore, it is important to determine the intensity of the boll infestation as well as the percentage. Records show an average of one worm per infested boll early in the season in lightly-infested fields. The number of worms per infested boll, however, increases in direct proportion to the increase in the percentage of bolls infested. Late in the season, fields in which 100 percent of the bolls are infested may show an average of over 9 worms per infested boll at the peak of the intensity of the infestation and as many as 18 worms have been found in a single boll at Presidio. Therefore, the figures showing percent of bolls infested are indirectly indicative of the damage done owing to their close correlation with the intensity of the infestation.

Field Intensity of Infestation

Owing to the different fruiting condition of the cotton plants as regards boll production in different years and in different fields in the same year, the comparative percentages of boll infestation mean little unless correlated with the above. A figure representing field intensity of infestation was, therefore, obtained by multiplying the average number of worms per boll by the average number of mature green bolls per plant. Records are available for 1929, 1930 and 1931. As shown in Table 2, the greatest intensity of infestation in 1929 was reached the second week of October at 6.73 worms per plant in bolls. In 1930, the average peak for all fields was 5.79 worms per plant in bolls the fourth week of September, while for 1931, the average peak for all fields was 8.99 worms per plant early in October.

Table 2. Average field intensity of infestation in cotton bolls caused by the pink bollworm, Presidio Valley, 1929-31

Date	1929	1930	1931
July 8-18			0.12
July 15-25		0.11	0.10
July 22-31		0.24	0.13
Aug. 1-8	0.7	0.27	0.12
Aug. 8-15	0.2	0.44	0.26
Aug. 15-23	0.44	0.52	0.48
Aug. 22-31	0.94	1.25	1.64
Aug. 29-Sept. 7	5.40	1.03	3.34
Sept. 6-14	4.97	3.28	3.90
Sept. 13-21	4.81	5.04	4.50
Sept. 20-30	3.98	5.79	7.50
Sept. 27-Oct. 3	6.09	3.49	5.20
Oct. 3-10	5.24	2.48	8.99
Oct. 11-16	6.73	4.69	4.94
Oct. 15-23	4.64	4.06	5.18
Oct. 22-31	5.93	3.38	4.73
Nov. 1-7		3.71	3.14
Nov. 8-14	2.27	3.67	4.97
Nov. 15-21		4.38	

FACTORS INFLUENCING INFESTATION IN COTTON

Aside from winter carryover, proximity to heavily infested fields, gins where proper clean-ups have not been made and the influx of moths by migration, the progress of pink bollworm infestation in any cotton field is dependent on soil type, plant growth and earliness of fruiting.

Soil Type

Fenton and Owen (1) found that the percentage of survival was smaller in the lighter sandy soils than in the heavier silty clay soils. It was, thus, thought possible that this might have a bearing on the infestation of the fields. Therefore, the fields where infestation records were made were grouped into two classes with reference to soil type: silty clay or mixed, with silty clay predominating; and sandy or sandy loam. Infestation records for the 4 years, 1928-31, are shown in Table 3 according to soil type. The number of fields per soil classification each year varied from 4 to 11. It was found, except for a few weekly variations, that each year the infestation was always heavier in cotton in the heavier silty clay soils than in the lighter sandy loam soils. The 4-year average shows this difference very plainly. Since cotton in the sandy loam soils tends to fruit earlier, and since this factor promotes an earlier and, therefore, subsequently heavier infestation, the difference in the infestations in the two soil types is even more remarkable. The influence of soil type does not necessarily mean that heavy infestations will not develop in cotton fields in sandy loam soils because such have been recorded. Other factors may influence this one way or the other. When, however, several fields of each soil classification are compared, especially over a period of years, the other influencing factors counterbalance each other. The effect of the soil type on field infestation is not due to its influence on plant growth, for luxuriant vegetative growth is produced in both types of soils in the Big Bend district.

Table 3. Comparative percent of boll infestation caused by the pink bollworm in cotton fields classified according to soil types, Presidio Valley, 1928-31

Date	Adobe predominating					Sand predominating				
	1928	1929	1930	1931	Average	1928	1929	1930	1931	Average
July 8-18				0.67	0.67			0	0.50	0.25
July 15-25			1.00	2.12	1.56			4.33	2.00	3.17
July 22-31			2.00	2.00	2.00			3.60	1.43	2.52
Aug. 1-8	0	6.00	3.00	2.20	2.80	0	1.50	3.60	1.13	1.56
Aug. 8-15	0	3.00	3.67	3.17	2.46	0	0.60	5.00	2.11	1.93
Aug. 15-23	0	7.00	3.75	4.67	3.86	0	1.20	3.00	4.27	2.12
Aug. 22-31	0	9.00	11.50	12.00	8.13	0	4.60	6.75	8.36	4.93
Aug.29-Sept.7	0.25	29.00	20.75	19.33	17.33	0.33	11.33	8.83	17.10	9.40
Sept. 5-14	4.5	37.33	29.00	18.17	22.25	2.00	4.00	14.00	20.36	10.09
Sept. 12-21	8.25	31.00	44.25	39.86	30.84	5.00	10.00	18.67	34.10	16.94
Sept. 19-30	9.50	43.25	51.50	52.86	39.28	8.33	25.60	23.17	41.10	24.55
Sept.26-Oct.4	14.67	59.00	58.00	67.57	49.81	16.50	41.00	24.92	49.76	33.05
Oct. 3-12	32.50	68.00	50.00	81.86	58.09	18.25	32.60	8.50	64.00	30.84
Oct. 10-16		82.67	64.67	90.86	79.40		44.92	32.05	75.09	50.69
Oct. 13-23	39.50	53.25	79.75	89.57	65.52	32.25	40.80	50.25	80.45	50.94
Oct. 21-31	51.25	67.85	84.75	90.29	73.54	44.25	45.75	66.25	82.55	59.70
Oct.28-Nov.6	57.25	62.00	87.00	89.14	73.85	54.00		63.58	75.18	64.25
Nov. 4-14	60.25	74.00	88.75	91.86	78.72	52.00	57.00	63.40	81.55	63.49
Nov. 11-21	64.25		89.00		76.63	51.67		69.00		60.34
Number of fields	4	4	4	7		4	5	6	11	

Type of Plant Growth

The intensity of pink bollworm infestation also is dependent on the rankness of growth in any cotton field. Where the stand is poor or the growth is stunted owing to lack of water, poor soil or other factors, unless heavily-infested fields are near by, pink bollworm infestation will rarely become serious. A rank, vegetative growth often is associated with heavy and late fruiting. Thus, the available supply of green bolls is greater when the infestation is at its peak and a larger moth population results. Moreover, the moths seem to be more attracted to a heavy, luxuriant growth for oviposition as the following observations indicate: in 1929, at Adobes, 50 net sweeps were made on each night of collection in thickly-spaced, luxuriantly-growing cotton and 50 in thinly-spaced, stunted cotton in the same field. A total of 119 moths, or 7.93 per night, was taken in 15 nights of collecting from September 19 to November 6 in the thrifty cotton and 41 or 2.73 per night for the same period in the stunted cotton.

Earliness of Fruiting

Other factors being equal, the earlier cotton plants fruit, the heavier the infestation. This is due to the fact that a considerable part of the moth emergence from long-cycle pupae is over before cotton fruits and the longevity of these long-cycle moths is short. Fields with plants squaring late will escape early moth infestation and, conversely, fields with plants squaring early will be exposed to more of the late-emerging moths. While no data were taken on the date of planting in fields in the Big Bend district where infestation records were made, this information was available to a certain extent in the time that the first bolls were picked for infestation records. In this district, availability of water has as much to do with the time that fields fruit as the date of planting. Excluding fields at Castolon and certain others in Presidio county where records were discontinued before the season was over due to various causes, there were 54 fields in which infestation records were kept from 1928 to 1931. To consolidate the data, the general period in days that the first bolls were picked is shown in Table 4, rather than the exact date. While yearly variations occurred, which were undoubtedly due to other causes influencing infestation such as nearness to infested material, soil type, heavy winter field carryover, and the like, the average shows that in general the earlier cotton fruits the greater the final percentage of infestation. Fields bearing their first mature bolls as early as July 15-18 reached a maximum infestation of 100 percent in 1931. Up to the period August 15-22, the average shows that the later the fields produced their first mature green bolls the lighter the final degree of infestation, with fields fruiting first for the period August 9-15 having the smallest average maximum percentage of infestation, namely 57.84 percent.

Table 4. Relation between date of fruiting of cotton on maximum percentage of boll infestation caused by the pink bollworm, Presidio Valley, 1928-31

	Date first bolls were picked and maximum percent of infestation							Number of fields
	July			August				
Year	15-18	20-31	27-31	1-8	9-15	15-22	22-Sept. 3	sampled
1928		77						1
				94				1
							61.56	9
1929		92						1
				78.75				4
					44.67			3
						74		2
1930		86.43						7
			66.5					2
							62.50	1
1931	100							8
		94.2						5
			85.5					2
				40.5				2
					71			2
						48.33		3
							65	1
Average	100							8
		87.41						14
			76.00					4
				71.08				7
					57.84			5
						61.17		5
							63.02	11

DAMAGE

Squares

Extensive artificial infestation of squares, using two larvae per square and also field observations in which hundreds of infested squares were dissected, revealed the fact that rarely does more than one larva infest a square in the Big Bend district. When squares half-grown or more are dissected, the larva within is usually partly grown. These squares show no signs of flaring or yellowing as they do when infested with the boll weevil. While ordinarily an infested square will bloom if it does not shed due to natural causes, in some cases it is completely destroyed, sheds and the worm cuts a round hole, leaves the square and pupates elsewhere. Typical square injury is shown in Figure 1. Sometimes if the square is shed the larva pupates within the square. Ohlendorf (8), working in the very heavily infested district of the Laguna, has shown that "little of the shedding of the young forms could be attributed to the pink bollworm."

Blooms

In case the infested square does not shed, a rosetted bloom results. These vary in shape from more or less perfect rosettes, Figure 2, to small, abnormal blooms. When these blooms are opened, the larva is seen to be in the last instar and is nearly full grown. Some of the anthers are still present. These blooms are held together by a few strands of silk and easily fly open if disturbed. Loftin (6) states that in the Laguna "40.8 percent of the normal blooms did not set bolls, but 67.6 percent of the infected blooms did not set bolls, a difference of 26.8 percent. Granting that under favorable conditions the natural tendency of the plant will be to reset these fruits, it is obvious that 26.8 percent of the blooms will make bolls at a much later date than they normally would, thereby subjecting them to a far heavier infestation; hence a greater amount of damage."

The rosetted bloom is a typical sign of pink bollworm infestation. These are only commonly seen, however, in fields where there is a heavy early square infestation. After bolls develop, quite often the square infestation decreases and rosetted blooms are seen less frequently. Then, as the boll infestation increases, so does that in squares, with resetted blooms again becoming more commonly seen.

Bolls

The greatest damage by the pink bollworm is done to cotton bolls. Other than the small round exit holes, Figure 3, there is no sign that bolls have been damaged until they begin to turn brown and start to crack open. The damage, so far as lint destruction is concerned, ranges from complete to where from one-third to more of the lint is still pickable. Quite often some locks in a boll will be utterly destroyed and others will contain some pickable cotton.

Lint

Willcocks states that loss to fiber is: (1) loss in quality due to not fuzzing out properly or damaged seeds break up in gin, pass along with fiber and get mixed up with it; (2) loss in weight of fiber produced per boll, this only in the partly attacked bolls that are picked. Ohlendorf (7) compared slightly-damaged cotton with that which was badly damaged and reports that the length of the staple was reduced, "uniformity" was from slightly below average to a mixed length of fiber in some cases, and the tensile strength was lower. When larvae enter immature bolls the lint is badly cut, since they feed outside of the seeds until the bolls are more mature. This cuts the fiber badly.

The most noticeable damage is the non-pickable cotton caused by multiple infestation. This term has been much criticized owing to the fact that cotton classed as non-pickable in some years, would be picked in others, and would be classed as non-pickable by some and as pickable by others in the same year. Ohlendorf (7) found the percent of non-pickable cotton to fluctuate with the price of cotton. With higher prices came lower percentages of non-pickable cotton. From 1915 to 1921, according to Ohlendorf (7), Schutz and Haskell estimated an average yearly loss record of 23.4 percent of the crop in the Laguna district of Mexico.

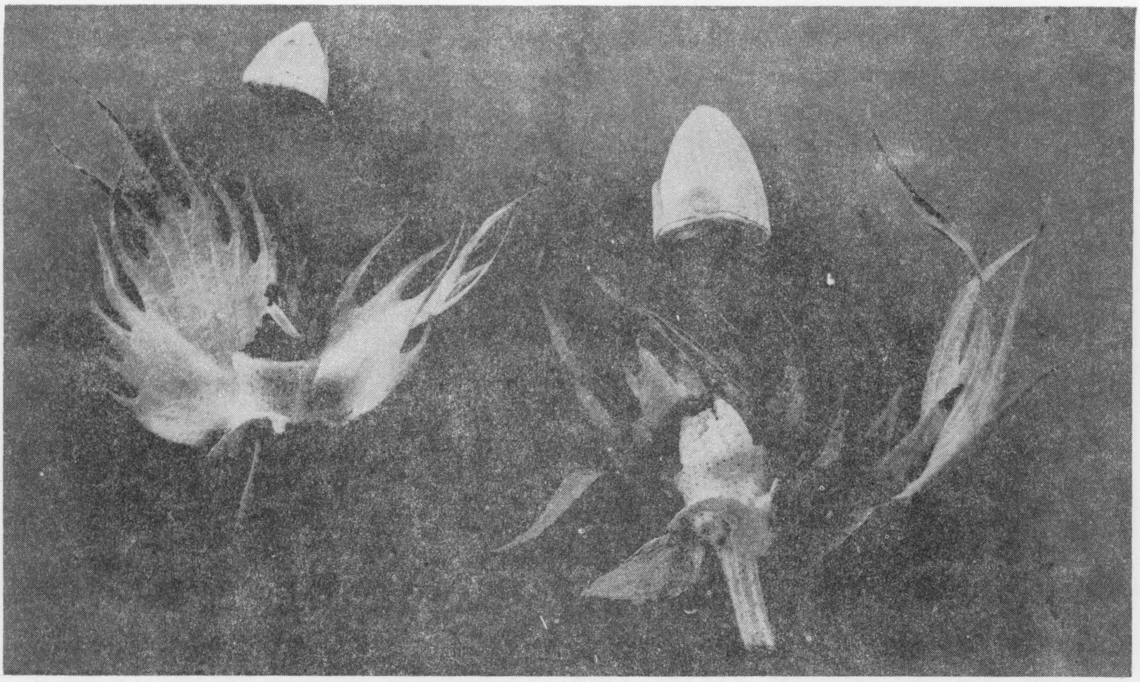

Figure 1. Damage to cotton squares caused by the pink bollworm.

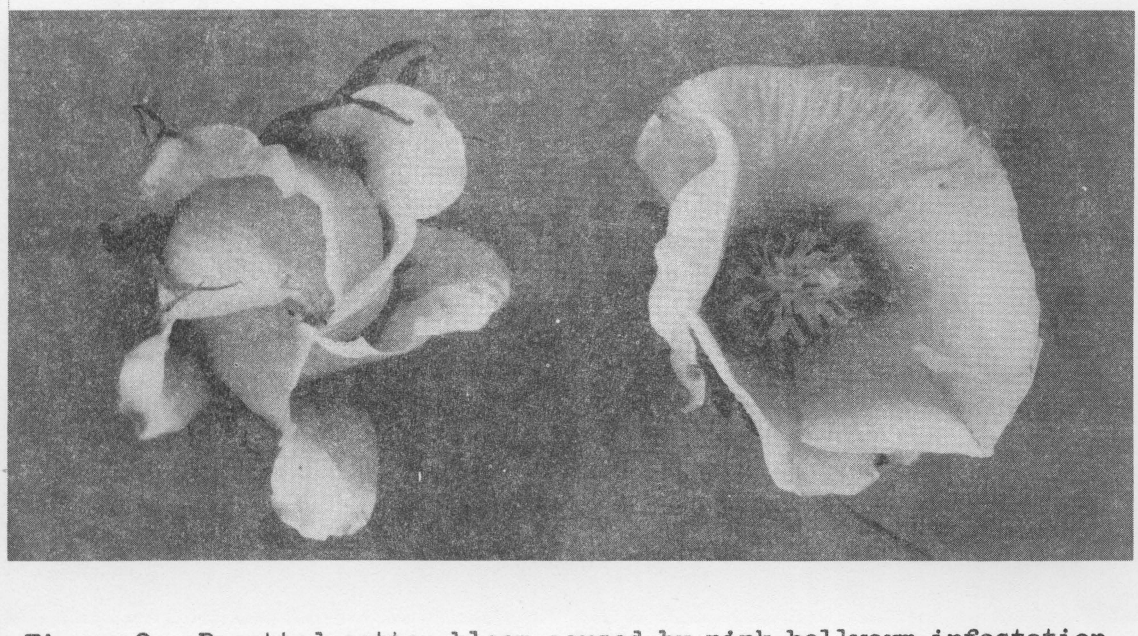

Figure 2. Rosetted cotton bloom caused by pink bollworm infestation compared with normal bloom.

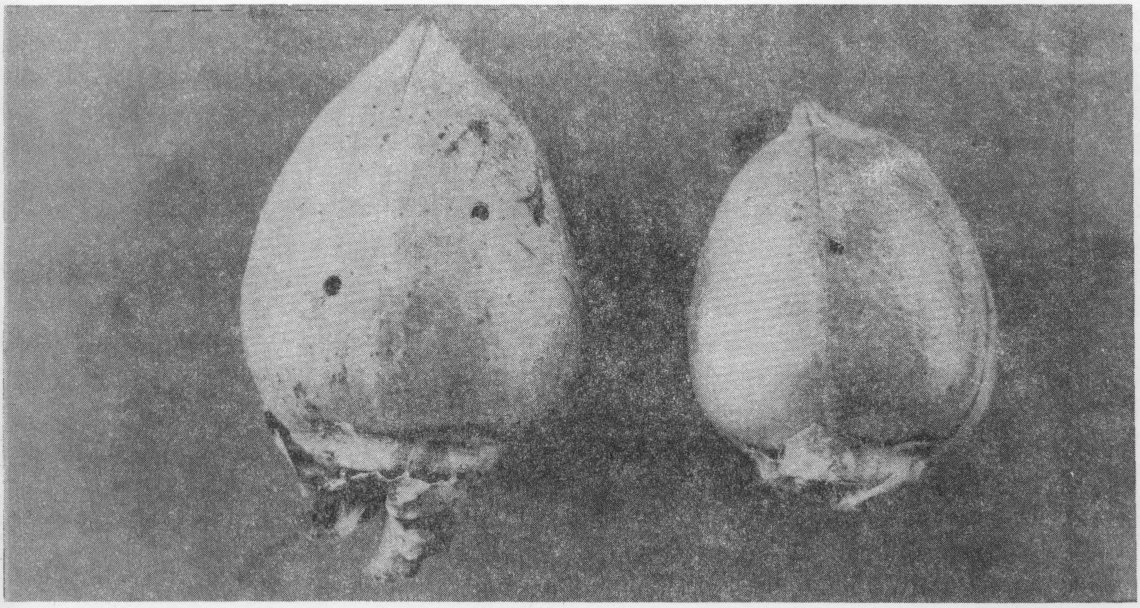

Figure 3. Green cotton bolls a few days before opening showing exit holes of the pink bollworm.

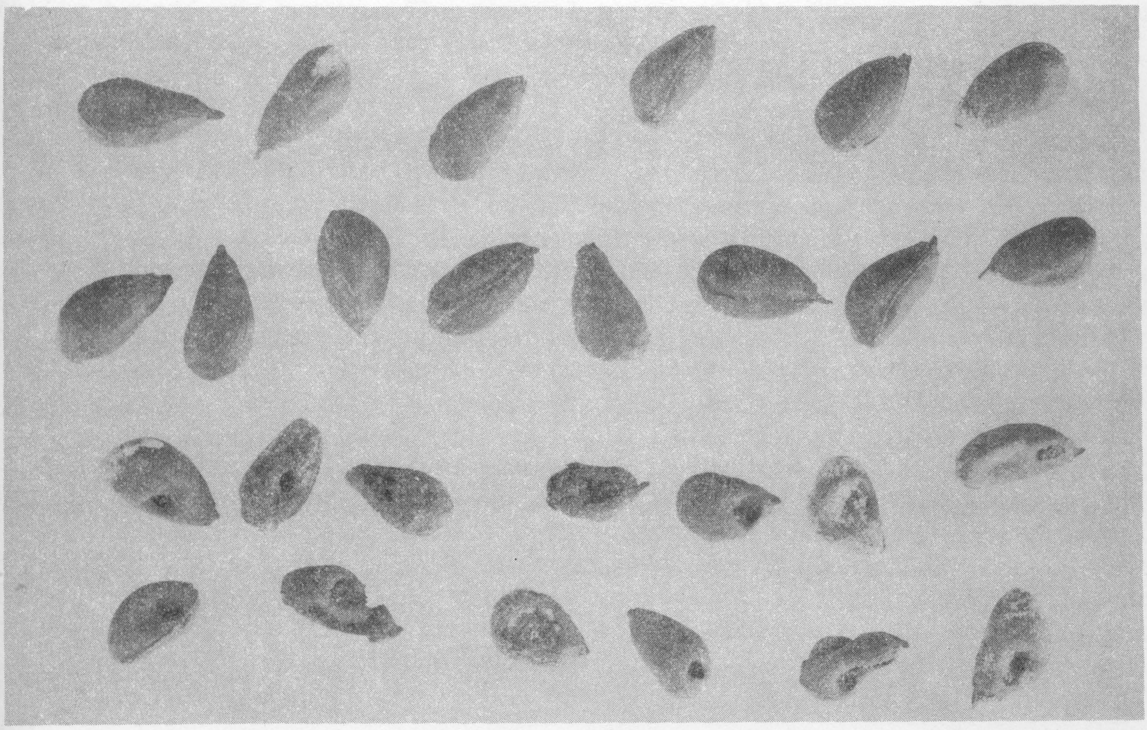

Figure 4. Delinted cotton seed showing character of injury to seed, lower two rows, as compared with normal seed, upper two rows.

Seed

In addition to destruction of lint, the seed also are severely injured and this represents an additional loss. When the lint is removed from damaged seed, this loss is quite apparent, Figure 4. Gough (4) states that in some manner the pink bollworm causes some of the sound seed in attacked bolls to lose weight and their germination also is affected. He also states that the number of seed per boll is reduced and it is obvious that the pink bollworm must affect the amount of lint produced: first, by reducing the number of seed per matured boll; second, by reducing the average weight of sound seed produced in attacked bolls; and third, by disturbing the development of immature attacked seed. The changes in the percentage of lint produced by damaged seed depends on the age of the seed at the time of the attack. First, if the seed is attacked at a very early stage, it disappears entirely, thus causing the reduction observed in the average number of seed set; second, attacked slightly later, part of the seed remains but sets no lint, thus causing the percentage to fall to zero; third, attached when nearing maturity, no damage is caused to the lint, but the seed loses substance, causing a rise in the percentage of lint. The damage to seed is stated by Ohlendorf (7) to average 4.70 percent reduction in weight. Loftin (6) found the loss in weight to run as high as 6.9 percent by weight.

DESCRIPTION OF STAGES

The Moth

The wing expanse is from 15 to 21 mm. The general coloring of the wings is metallic or coppery brown. The general shape of the fore and hind wings and pattern of the markings are shown in Figure 5.

The Egg

The egg is described by Loftin (6) as "small, elongate oval, somewhat broader at one end; length from 0.4 to 0.6 mm., breadth 0.2 to 0.3 mm.; shell iridescent, pearly white with a greenish tint when first deposited, turning to almost red before hatching; surface firmly reticulated with regular longitudinal lines or ridges with irregular cross-connections." Typical egg clusters on the inner surface of a cotton boll involucre are shown in Figure 6.

The Larva

Four instars of the larva are shown in Figures 7, 8, 9 and 10, in comparison with the head and upper part of an ordinary pin for size relationship. The newly hatched larvae are pale cadmium yellow in color with the head and thoracic shield black. The full grown larva is from 11 to 13 mm. long and pink in coloration. The pink coloring is more or less variable in intensity, the long-cycle larvae being of a decided pink, rose pink or prawn pink color, whereas in the summer or short-cycle larvae, the coloring is less intense.

The Pupa

The pupa is 6 to 10 mm. long and reddish brown in color, depending upon the age. The general shape and other characteristics are shown in Figure 11.

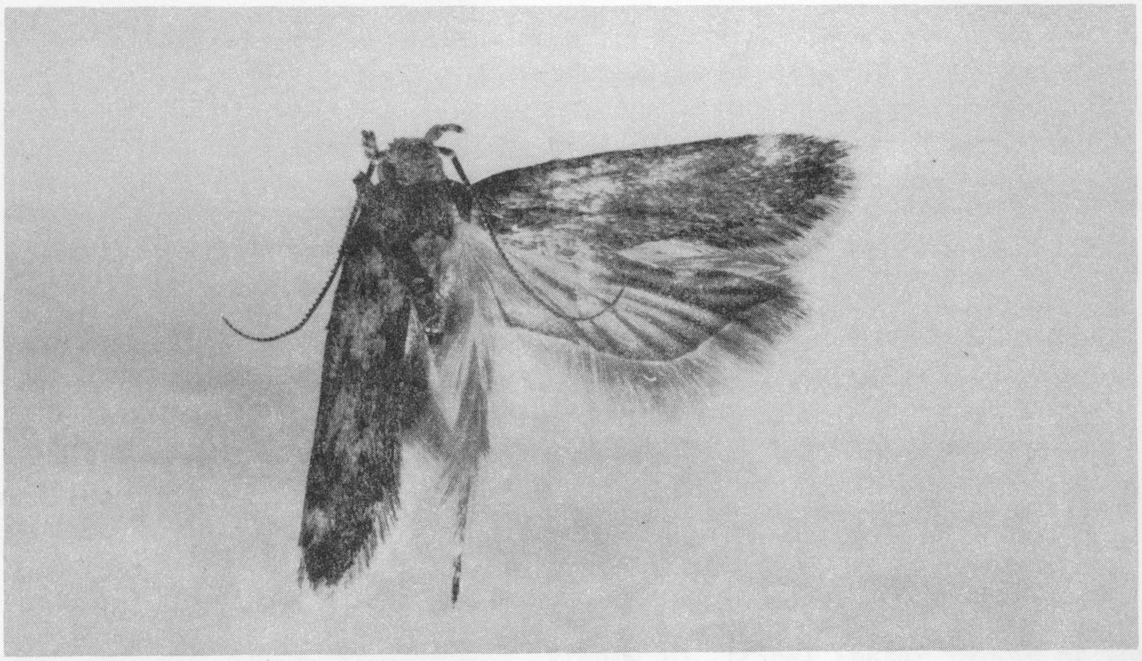

Figure 5. Pink bollworm moth with right fore and hind wings spread to show color pattern and hind wing venation. Enlarged 8 times.

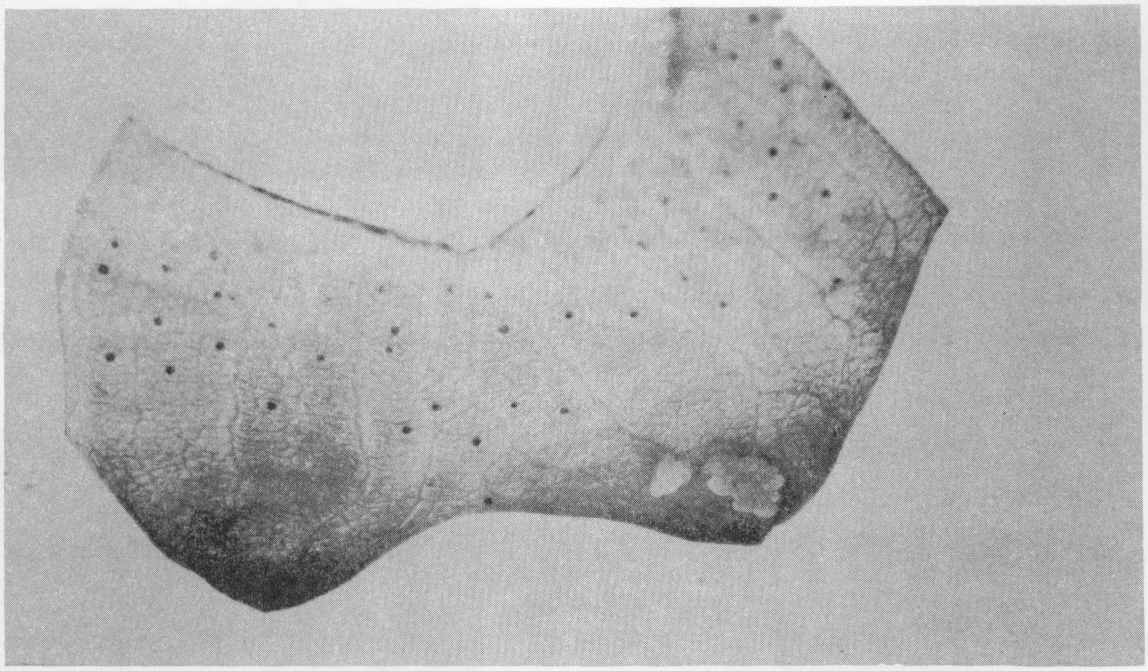

Figure 6. Egg masses of the pink bollworm on under side of boll involucre. Enlarged 10 times.

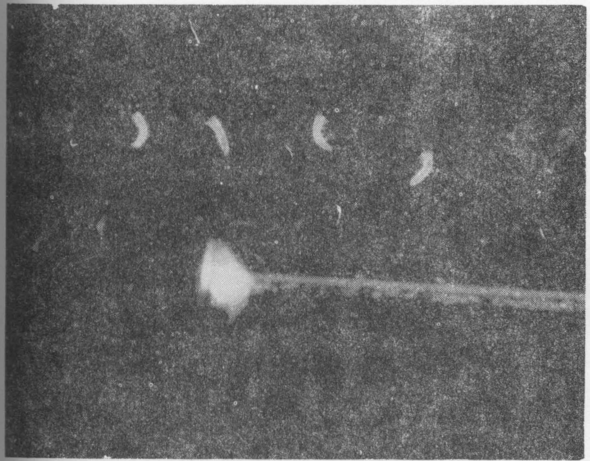

Figure 7. First instar pink bollworm larvae with head of common pin for size comparison.

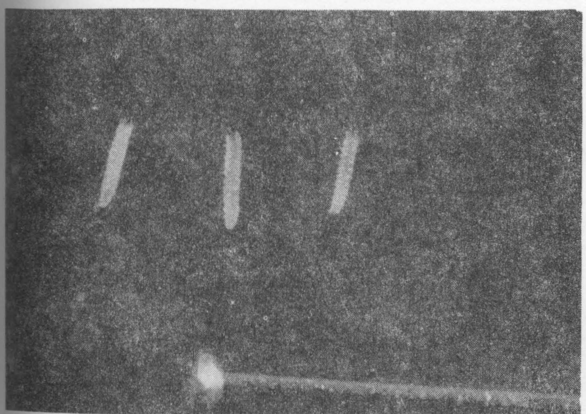

Figure 8. Early intermediate instar larvae of the pink bollworm with head of common pin for size comparison.

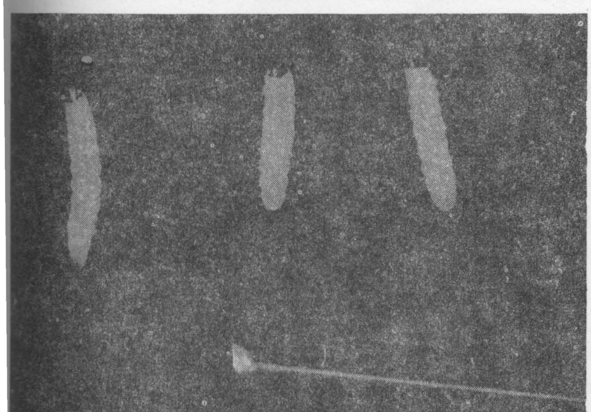

Figure 9. Late intermediate instar larvae of the pink bollworm with head of common pin for size comparison.

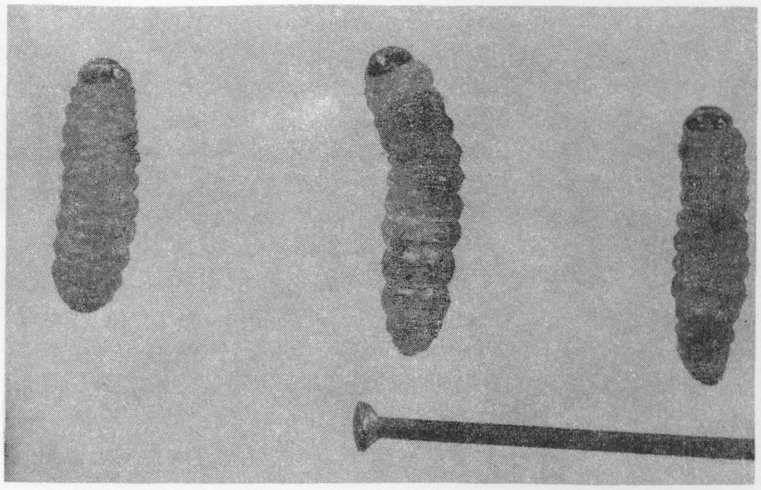

Figure 10. Final instar larvae of the pink bollworm with head of common pin for size comparison.

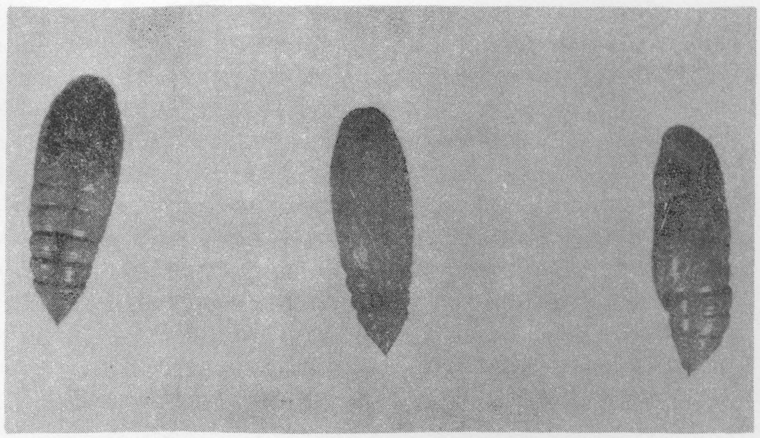

Figure 11. Pupae of the pink bollworm.

THE LIFE CYCLE

The Moth

During the day, the moths remain hidden in cracks in the soil, under flat objects, leaves, etc. If disturbed during the day, the flight is very short and rapid and when the moth alights, it runs rapidly for a place of concealment. Moths released from traps during the day immediately seek shelter in the soil if the sun is shining. If cloudy, sometimes the flight is upwards as far as the eye can see. Flight activity does not begin until dark and usually ceases when the temperature falls to 60° F. or below, or at the first faint signs of dawn in the early morning hours. In heavily-infested fields, flight has been observed all night when temperature conditions were favorable.

Longevity Before Fruiting of Cotton. Since a considerable part of the emergence of long-cycle moths took place before the first squares were developed on cotton, it was of considerable importance to determine how long these early emerged long-cycle moths lived under the most favorable conditions. Three-years' records on this point indicate that prior to square formation by the cotton plant the average period of life was short, not over 2 weeks under the most favorable conditions. The presence of considerable moisture in the soil increased longevity. This indicated that rains occurring during April and May would be decidedly favorable for these long-cycle moths. Also, moths emerging in cotton fields where the soil was moist due to irrigation would live longer than those emerging from pupae in fields in fallow.

In 1929, the moths used in the longevity tests were those recovered from the field hibernation cages. Since it is now known that most of these moths were approximately 1 day old when recovered from the moth traps, this fact was considered in comparing 1929 records with those of 1931 when the exact date of moth emergence from the pupa was known. A cage was used in these tests which was 1'x2'x18" in dimensions, with screen sides, glass top, board ends and bottom, with one end fitted with a black cloth sleeve. Several combinations of moisture and shelter for the moths were tested. The soil in the cages was either kept wet by frequent waterings or was left dry, and some cages were provided with shelter such as okra hulls, growing weeds, flowers, etc. In some cages food was supplied in the form of water and sugar solution. It was soon observed that moisture was an important factor in extending moth longevity, so additional cages were placed in observation in which a high percentage of humidity was maintained by covering the screen tops of lantern globes over clay pots containing moist soil with a layer of water-saturated sphagnum moss. The type of soil was also varied and some cages were provided with sandy soil and others with adobe soil.

Summarizing all tests for 1929 (Table 5), it was found that for each combination of conditions the female moths lived, on an average, for a somewhat longer period than did males. The minimum length of life for any moth was 1 day and the maximum was 27 days. The lowest average length of life was found for moths in cages with dry soil, either adobe or sandy, where it ranged from 2.59 days for 97 males in cages over dry adobe soil to 3.50 days for 71 females in cages over dry sandy soil. When the soil in the cages was kept moist, the longevity more than doubled. Finally, when the moisture conditions were further increased by covering the tops of the cages with dampened sphagnum moss, the greatest average longevity was recorded. Under these conditions in sandy soil, the mean longevity for 149 males was 10.28 days and for 124 females it was 12.19 days. The comparatively small number of records for humid air cages with adobe soil showed an even larger average longevity.

Table 5. Presquare longevity of pink bollworm moths, Presidio, 1929-31.

Males: Number of Records	Males: Number of Moth days	Males: Number of days longevity Average	Males: Number of days longevity Maximum	Males: Number of days longevity Minimum	Females: Number of Records	Females: Number of Moth days	Females: Number of days longevity Average	Females: Number of days longevity Maximum	Females: Number of days longevity Minimum	Mean temperature degrees F.	Average percent relative humidity	Soil type	Treatment	Date
									1929					
97	257	2.59	7	1	109	338	3.07	7	1		-	Adobe	Soil dry	
71	224	3.15	10	1	71	256	3.50	11	1		-	Sandy	Soil dry	
84	573	6.84	22	1	102	803	7.87	19	1	79.77	-	Adobe	Soil wet	April 8 to June 14
126	989	7.85	22	1	135	1305	9.67	22	1		-	Sandy	Soil wet	
149	1532	10.28	27	1	124	1512	12.19	26	1		-	Sandy	High percent	
11	143	13.00	22	6	8	116	14.15	22	8		-	Adobe	air humidity	
									1930					
38	114	3.0	6	2	46	143	3.1	6	2	73.3-77.3	43.30	Mixed	Soil dry	April, May and June
26	229	8.8	24	2	44	400	9.1	23	3	75.4-82.2	76.15	Mixed	Soil watered	
17	131	7.7	17	2	25	243	9.7	18	2	76.6-83.3	81.27	Mixed	Soil watered	
16	153	9.56	19	2	22	197	8.95	21	2	75.7-81.9	82.37	Mixed	Soil watered	
									1931					
45	152	3.38	5	1	48	188	3.92	6	2	79.5	47.46	Mixed	Soil dry, no drinking water	May 7-June 5
34	272	8.C	15	1	44	319	7.25	16	1	81.3	46.70	Mixed	Soil dry plus drinking water	May 11-June 14
31	270	8.7	16	2	37	392	10.6	21	2	81.1	57.69	Mixed	Soil moist, no drinking water	May 9-June 15
33	360	10.9	21	2	32	346	10.8	19	3	81.4	69.13	Mixed	Soil wet, no drinking water	May 10-June 17
									Average					
251	747	2.98	10	1	274	925	3.38	11	1	-	-	-	Soil dry, no drinking water	-
34	272	8.00	15	1	44	319	7.25	16	1	-	-	-	Soil dry, plus drinking water	-
493	4380	8.88	27	1	529	5314	10.05	26	1	-	-	-	Soil watered, no drinking water	-

Due to the very late and small moth emergence from the various cages in 1930, longevity experiments were not started until April 24. In these tests, moths also were used which had emerged from the various hibernation cages and were, therefore, approximately 1 day old at the start of each test. The longevity cage used in the 1929 work was supplanted with the clay pot-lantern globe type found to be more satisfactory in the biological work according to Owen and Calhoun (8). Temperature records were taken from a thermograph in close proximity to the cages and, as will be seen from Table 5, varied little for all of the tests. Humidity readings were taken with a whirl psychrometer inserted in the top of the lantern globe. Readings were made at 8:00 a.m., 12 noon and 5:00 p.m. daily, and averages were taken from these. No food was given the moths during these experiments.

Humidity conditions were varied in four series of tests, the average varying from 43.30 percent for the dry soil to 82.37 percent for the very moist cage conditions. In maintaining these conditions, water was added to the soil in the pots each morning. As shown in Table 5, humidity appeared to have an important influence on longevity. The shortest length of life, averaging approximately 3 days, was found in the dry soil cages where the humidity averaged 43.30 percent. In cages where the soil was kept wet and the air moist and where the humidity averaged 82.37 percent, the mean longevity ranged from 8.95 days for 22 females to 9.56 days for 16 males. The range in longevity varied from 2 to 24 days.

In 1931, the experiments on presquare moth longevity were further refined in that only long-cycle moths were used for which the exact time of emergence from the pupal case was known. It was demonstrated that year that available drinking water was of equal importance as the humidity conditions. It, therefore, appeared likely that in the previous years, the increased moth longevity in some of the cages with wet soils also was due as much to the water taken up by the moths as to the percent of humidity in the cages. As shown in Table 5, the mean longevity in cages with dry soil was still approximately 3 days and the average longevity increased in direct ratio with the presence of available water or an increase in humidity. One series of tests was made in which the soil in the cages was dry and a second in which the soil was dry but drinking water was provided moths in a small container. As seen from the table, the small amount of drinking water did not affect the average percent of humidity in the cages appreciably; yet the mean longevity more than doubled. In the other two sets of cages, the mean humidity averaged 57.69 and 69.13 percent, respectively. The difference in the relative percentages of humidity was due to the degree of wetness of the soil. No drinking water was available, yet the mean longevity was greater than in the cages with dry soil with drinking water and of the two sets of cage conditions, the mean longevity was the greater when the relative humidity was the greater. Thus, although water is not necessary for drinking, it must either be available or present in some form for any appreciable moth longevity.

To determine whether moths actually drank water, a series of tests in which 67 moths were used was conducted in cages with dry soil in which, however, the water in the stender dish was poisoned with sodium arsenite. Moths began to die in 2 hours, 43 were dead at the end of 23 hours at which time only 1 in the check cage had died, and all were dead at the end of 4 days; while but 20 percent of the moths were dead in the check cage at this date. In the check cage, 11 days elapsed before all of the moths died. In a cage in which the soil was watered, but where there also was poisoned water in a stender dish, the mean longevity of the moths was greater than for those in cages with dry soil and where poisoned water also was present. This showed that moths still drank the poisoned water even when the soil was watered but that less of it was taken than in the cages with dry soil. Therefore, it appeared that drinking water was not as necessary to the moth under moist conditions as it was when the soil was dry. In a cage where the soil was watered

Table 6. Comparison of longevity of pink bollworm moths after cotton fruited from stored refrigerated seed and green cotton bolls, Presidio, 1929-30.

Year	Males					Females				
	Number of		Number of days longevity			Number of		Number of days longevity		
	Records	Moth-days	Average	Maximum	Minimum	Records	Moth-days	Average	Maximum	Minimum
Material from seed										
1929	27	273	10.11	18	3	24	267	11.13	19	3
1930	86	753	8.76	23	2	53	589	11.11	24	3
1929 and 1930	113	1026	9.08	23	2	77	856	11.12	24	3
Material from bolls										
1929	39	427	10.95	30	2	42	760	18.10	36	3
1930	78	932	11.95	24	1	41	619	15.10	26	4
1929 and 1930	117	1359	11.62	30	1	83	1379	16.61	36	3

Table 7. Longevity of pink bollworm moths in cages, insectary, Presidio, May 31-November 15, 1931

Source of material	Females					Males					Period covered	Percent mean relative humidity	Mean temperature for period degrees F.
	Number of		Number of days longevity			Number of		Number of days longevity					
	Records	Moth-days	Average	Maximum	Minimum	Records	Moth-days	Average	Maximum	Minimum			
Overwintered brood	37	440	11.89	23	3	53	584	11.02	27	2	May 31-July 15	65.3	84.6
Squares	138	1230	8.91	22	2	104	894	8.60	29	2	July 3-Nov. 15	76.3	81.6
Bolls	67	764	11.40	20	4	83	971	11.70	28	2	July 28-Oct.30	78.3	80.7

with poisoned water, the mean moth longevity was longer than in the above two tests where the poisoned water was kept in a stender dish, but was still somewhat shorter than in the cage with dry soil with unpoisoned water in a stender dish. This appeared to show that the moths drank some of the excess water from the wet soil. Finally, in the cage in which the soil was watered with unpoisoned water, the mean longevity was the greatest of all.

Longevity After Fruiting of Cotton. During 1929 and 1930, the longevity of both sexes was compared for moths reared from refrigerated seed (long-cycle moths) and moths reared from green cotton bolls (short-cycle moths) (Table 6). It was found that the average length of life for 113 males for the 2-year period from seed material was 9.08 days, and for 117 males from green bolls it was 11.62 days. Similarly, the average longevity of 77 females from refrigerated seed was 11.12 days and for 83 females from green bolls it was 16.61 days. The range extended from 1 to 30 days for males and from 3 to 36 days for females.

During these 2 years, the mean longevity for both sexes from both types of materials was found to be influenced considerably by temperature. Excluding the one record at an average temperature of 87.33° F., it was found that there was a natural range of from 2 to 13 days at temperatures averaging from 80.08 to 82.88° F. Below these temperatures, the average longevity increased in direct ratio with the lowering of the mean temperatures during the life of the moth, the increase being fairly uniform for longevity periods of from 14 to 30 days.

During 1931, the longevity was studied according to the brood of the moth and this was further correlated with the type of material on which the larva had developed (Table 7). It was found that the average longevity of both sexes which had transformed from larvae developed in squares was notably less than that of moths from refrigerated seed or from green bolls. That year there was very little difference between the longevity of moths from seed and from bolls.

Time of Emergence of Moths. The moths emerged from the pupal cases mostly during the morning hours, most of them between 8:00 and 9:00 a.m. at Presidio (Table 8). Later in the season when the temperatures were lower, the time of greatest emergence was somewhat later. Also, under certain conditions, some moths emerged late in the afternoon but this was an exception. After the wings had fully expanded and hardened, the moths remained quiescent until dark.

Table 8. Time of day moth emergence from short-cycle pupae occurred, insectary, Presidio, July to November, 1931

	Time of day and number of moths emerging									
Generation	Before: 8 a.m.	8-9 a.m.	9-10 a.m.	10-11 a.m.	11-12 a.m.	12m.- 1 p.m.	1-2 p.m.	2-3 p.m.	3-4 p.m.	4-5 p.m.
1	130	115	102	18	2	3	0	3	0	0
2	114	113	50	15	2	13	3	4	1	0
3	183	266	146	78	8	11	3	0	0	0
4	74	125	89	27	4	5	3	1	0	0
5	11	34	42	12	3	5	0	2	0	0
Totals	512	653	429	150	19	37	9	10	1	0
Percent of total	28.13	35.88	23.57	8.24	1.1	2.0	0.5	0.5	0.08	0.0

Oviposition. Records on the duration of the preoviposition period of moths of the different generations were taken during 1931. Averages based on the first date of egg deposition for 160 females showed that the duration of this period ranged from 2.28 days for females from larvae developed in bolls to 4.30 days for females from long-cycle larvae from 1931 seed material (Table 9). The average oviposition period for these 160 females ranged from 4.88 days for females from larvae developed in squares to 7.28 days for females from larvae developed in green bolls (Table 9).

Table 9. Summary of preoviposition and oviposition periods of pink bollworm moths insectary, Presidio, 1931[1/]

Period covered	Source of material	Number of broods	Number of records	Average number of days for: Preoviposition period	Average number of days for: Oviposition period
May 31-July 15	Overwintered brood	1	13	4.30	7.15
July 3-Nov. 15	Squares	5	94	2.40	4.88
July 28-Oct. 28	Green bolls	3	53	2.28	7.28

1/ Only females laying fertile eggs and with complete records included.

Excluding the July records for 1929 because of loss of eggs in the soil in the first type of oviposition cages, records for 3 years, 1929-31, on 254 fertile egg-laying females showed that an average of 111.05 eggs was deposited per female (Table 10). Over the 3-year period, the range in total egg deposition per female varied from 4 to 448. The average total egg deposition per female during 1931 was greater for females reared from green bolls than for those from squares or overwintered cotton seed material. The average fecundity, or total egg laying possibility, for these 254 females for the 3-year period was 121.67. The maximum fecundity recorded was 451 eggs for a female under observation in 1930 (Table 11).

Table 10. Summary of egg deposition by female pink bollworm moths laying fertile eggs, insectary, Presidio, 1929-31

Year	Months	Number of: Records	Number of: Eggs	Number of eggs laid per female: Average	Number of eggs laid per female: Maximum	Number of eggs laid per female: Minimum
1929	August-October	59	6,155	104.32	320	8
1930	June-November	35	5,053	144.37	448	6
1931	May-November	160	16,999	106.24	434	4
1929-1931	May-November	254	28,207	111.05	448	4

Table 11. Summary of fecundity of female pink bollworm moths laying fertile eggs, insectary, Presidio, 1929-31

Year	Months	Number of: Records	Number of: Eggs	Number of eggs per female: Average	Number of eggs per female: Maximum	Number of eggs per female: Minimum
1929	August-October	59	6,663	112.93	323	
1930	June-November	35	5,422	154.91	451	9
1931	May-November	160	18,803	117.52	434	6
1929-1931	May-November	254	30,888	121.61	451	6

Table 12. Total daily oviposition of female pink bollworm moths during their oviposition period, insectary, Presidio, 1930-31

Year	Number of records	Total daily oviposition from date of first egg deposition: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Totals
1930	35	1258	825	700	513	518	316	307	271	109	87	55	41	31	10	1			5,042
1931	160	4292	3234	2765	2255	1639	1113	754	380	261	184	44	29	30	15	0	0	4	16,999
1930-1931	195	5550	4059	3465	2768	2157	1429	1061	651	370	271	99	70	61	25	1	0	4	22,041

Table 13. Total daily oviposition of female pink bollworm moths computed from time of emergency, insectary, Presidio, 1930-31

Year	Number of records	Total daily oviposition from date of emergence: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Totals
1930	35		239	637	608	466	544	632	576	426	284	197	170	126	81	38	12	3	3	-	5,042
1931	160		1473	2648	3076	2727	2181	1574	1127	870	515	394	177	120	35	51	17	10	0	4	16,999
1930-1931	195		1712	3285	3684	3193	2725	2206	1703	1296	799	591	347	246	116	89	29	13	3	4	22,041

Rate of Egg Deposition During Oviposition Period. Records for 1930 and 1931 showed that, once oviposition had started, the greatest total egg deposition for any night usually occurred on the first night of oviposition (Table 12). These records are based on observations of 35 females in 1930 from refrigerated seed and green bolls and 160 females in 1931 from refrigerated seed, squares and green bolls. As would be expected, individual variations from this average were observed.

Rate of Egg Deposition from Date of Moth Emergence. As previously shown, the duration of the preoviposition period varied considerably. Taking this fact into consideration, it was found during 1930 that the average maximum nightly oviposition from date of moth emergence for 35 females from June to November from both refrigerated seed and green bolls was on the third night. In 1931, the average peak of oviposition of 160 females was reached on the fourth night following emergence (Table 13). During both years, however, variations from the above were noted both as to individual moths and generations.

The Egg

Location on Plant. During the early part of the season before boll development, eggs are deposited promiscuously over the cotton plant. Some are laid singly on the buds of the plant, others on the leaves and stems. A few are deposited in the soil. Later, when bolls are developed, most of the eggs are laid under the boll involucre in small masses of from 10 to 12 or more (Table 14).

Table 14. Location of pink bollworm eggs on cotton plants in the field, Presidio, August 17-October 10, 1929-31

Location of eggs on plants	1929 Aug. 17-Sept. 10-Oct. 17 Number of eggs	1929 Percent of total oviposition	1930 Aug. 29-Oct. 1 Number of eggs	1930 Percent of total oviposition	1931 Sept. 12-Oct. 10 Number of eggs	1931 Percent of total oviposition	1929-31 Aug. 17-Oct. 10 Number of eggs	1929-31 Percent of total oviposition
Buds	5	0.4	116	7.4	29	4.4	150	4.25
Under boll involucre	1224	94.4	1347	85.9	550	82.7	3121	88.44
Leaves	10	0.8	11	0.7	6	0.9	27	0.76
Squares	0	0	0	0	0	0	0	0
Boll surface	51	3.9	38	2.4	59	8.8	148	4.19
Stems	7	0.5	55	3.6	21	3.2	83	2.36
Totals	1297	100	1567	100	665	100	3529	100

Incubation Period. The duration of the incubation period is dependent on temperature. Records taken during 1931 showed that the shortest mean incubation period for any egg mass was 4.6 days at a mean temperature of 85.4° F. and the longest was 12.7 days at a mean temperature of 58.2° F. It was found that the hatching period of each egg mass usually extended over a period of 2 days and rarely started before 8:00 a.m. No hatching was observed to take place at night.

The Short-cycle Larva

The young larvae are very active after hatching but must find the fruiting part of cotton or of a suitable malvaceous plant within 1 to 2 days or death results. Under high temperature conditions, 90 percent of first instar larvae were dead at the end of 24 hours, even when supplied with green cotton leaves. The entrance holes of the young larvae in squares and bolls can be seen readily on close inspection. Once in the cotton square, the larva feeds on the immature anthers. Growth seems to be synchronized with the development of the square. The square is not usually injured, as in the case of the boll weevil larva, but continues to grow and develop. Quite often, however, the resulting bloom is distorted and again it is normal except the unfolding petals are held together with a few strands of silk spun by the larva, which is now practically fully developed. When the bloom sheds, the larva completes its development within and also may pupate in the bloom. If the larva is not fully developed, it sometimes feeds down into the young boll. Under conditions as they exist at Presidio, an average of approximately 10 days was spent within the square during the feeding period of the larva (Table 15). The range in duration of the feeding period in squares was from 6 to 18 days.

In bolls, the young larva cuts through until it reaches the tough inner membrane which separates the carpel of the boll from the immature cotton within. Then, the larva tunnels for a varying distance just between this membrane and the carpel producing a very characteristic watery mine, which is one indication of pink bollworm infestation. Sometimes this mine is made along the partition of the carpels of two adjacent locks. Soon the young larva cuts its way through to the lint and then bores down within in search for the developing cotton seed. Once a seed is located, the larva tunnels within and continues its development within the seed, which it usually completely destroys, depending on the age and size of the seed attacked. If the seed is immature or small, the larva attacks and destroys a second one. Heavily-infested bolls present an altogether different appearance than those lightly infested for the many larvae not only destroy the seed but also the lint, and the entire interior of the boll is rendered a diseased, discolored mass of abnormal tissue. After reaching its maximum growth, the larva, if it is of the short-cycle type, cuts its way out of the boll, sometimes cutting a hole through the partition wall between locks. These exit holes made by the larvae are clearly cut and are of the size of small bird shot. After leaving the boll, the larva may spin a cocoon in and among the surface litter of the cotton field, attached to the main tap root a few inches below the crown, or the cocoon may be spun in the loose soil. Under certain conditions, the short-cycle larva remains in the boll. An average of approximately 16½ days was spent by the larva within the boll, the range being from 11 to 25 days (Table 16).

The Long-cycle Larva

If the larva is of the long-cycle type, it may or may not leave the boll. Few long-cycle larvae are found in squares. If the larva remains within the boll, it either curls up within a single seed, the opening of which is spun over, or it fastens two adjacent seeds together. The latter are the familiar "double seed" found in infested cotton at the gins. If the long-cycle larva leaves the boll, it spins a round, compact cocoon quite different from the somewhat larger more oval one of the short-cycle larva. Between the termination of the feeding period of the long-cycle larva and its transition into the pupal stage is a long diapause which usually terminates early the next season but which may last as long as 31 months, according to Ballou as cited by Hunter (5).

The Prepupa and Pupa

Following the feeding period of the short-cycle larva, or the diapause of the long-cycle larva, is a prepupal period during which no food is taken and the necessary changes are made for the transition into the pupal stage. This stage lasted an average of 3.75 days for short-cycle larvae developed in squares and 3.28 days for short-cycle larvae from bolls (Tables 15 and 16). The range for both types extended from 1 to 21 days. Following this phase, the larva transforms to the

Table 15. Duration of development of each stage of the life cycle of the pink bollworm by generations in squares, Presidio, June to November 1931

Generation	Number of records: Female	Number of records: Male	Days incubation	Days feeding period: Female	Days feeding period: Male	Days prepupal period: Female	Days prepupal period: Male	Days pupal period: Female	Days pupal period: Male	Days average development: Female	Days average development: Male	Period covered	Mean temperature degrees F.
1	203	175	4.84	10.95	10.99	3.32	3.43	7.63	7.97	26.74	27.23	June 7-July 17	84.90
2	110	90	4.51	10.23	10.56	3.69	3.42	7.53	7.98	25.96	26.47	July 3-Aug. 12	84.46
3	64	62	4.50	8.33	8.71	4.26	4.60	7.72	8.06	24.81	25.87	July 28-Sept. 2	82.20
4	63	74	4.50	8.59	8.69	3.36	3.90	7.51	7.73	23.96	24.82	Aug. 21-Sept. 26	83.20
5	68	42	4.50	10.06	9.86	4.44	4.64	9.49	10.40	28.49	29.40	Sept. 15-Nov. 2	77.93
6	4	3	4.78	11.75	13.00	6.50	5.67	21.00	23.33	44.00	46.83	Oct. 11-Nov. 30	66.46
Totals	512	446	4443.0	5153.0	4510.0	1892.0	1695.0	4074.0	3691.0	13494.0	11964.0		
Average			4.64	10.06	10.11	3.70	3.80	7.96	8.28	26.36	26.83		

Table 16. Duration of development of each stage of the life cycle of the pink bollworm by generations in bolls, Presidio, July 3 to October 4, 1931

Generation	Number of records: Female	Number of records: Male	Days incubation	Days feeding period: Female	Days feeding period: Male	Days prepupal period: Female	Days prepupal period: Male	Days pupal period: Female	Days pupal period: Male	Days total development: Female	Days total development: Male	Period covered	Mean temperature degrees F.
1			No development in bolls at this time									June 7-July 17	
2	58	59	4.60	17.33	17.13	3.04	3.25	8.17	8.51	33.15	33.48	July 3-Aug. 11	84.40
3	255	313	4.50	16.39	16.17	2.93	3.15	8.06	8.28	31.88	32.10	Aug. 2-Sept. 21	82.46
4	104	89	4.50	16.63	17.15	3.80	4.38	9.80	10.35	34.73	36.38	Sept. 2-Nov. 4	79.10
5			Installations were made from eggs laid Oct. 4-7. All long-cycle larvae. None transforming.									Oct. 4-Over winter	Oct.4-Nov.1-74.40
6			No similar generation in bolls									Oct. 11-Nov. 30	
Totals	417	461	3963.0	6915.0	7600.0	1318.0	1567.0	3549.0	4014.0	13665.5	15260.5		
Average			4.51	16.58	16.49	3.16	3.40	8.51	8.71	32.77	33.10		

pupa. This stage lasted from 6 to 24 days, averaging 8.12 days under optimum temperature conditions for larvae developed in squares and 8.61 days for larvae developed in bolls (Table 15 and 16).

Comparison of Flight in Different Years. According to the flight screens, the migration was very light in 1928 and 1929 but increased considerably during 1930 and still further in 1931. A comparison of the total number of moths taken on the screens, together with other pertinent data, is shown in Table 17. The actual number of moths caught in 1930 and 1931 was twice that shown in the table but the flight screens were twice standard size during the latter years. The infestation percentages are given for the entire district rather than for those fields where the screens were located. These infestation percentages have shown a decided trend to increase from year to year, indicating a relationship with the increase in moth migration. The average number of moths caught per night per 100 sweeps for all fields did not show a distinct correlation with either the district infestation percentage average or the comparative migration in different years. Until 1931, the heaviest moth flight had taken place during October with none recorded for December. In 1931, however, while there was a greater migration during October than during this month in any previous year, the total moth movement in November was still greater and a few moths were taken in early December.

NUMBER AND DEVELOPMENT OF THE GENERATIONS

In 1931, there were six generations in squares and three and a partial fourth in bolls. The first generation was entirely developed in cotton squares. Beginning with early July, however, development took place in both squares and bolls, preferably in bolls. Not until the boll infestation became heavy, or when there was an unusually heavy winter survival, in which case the square infestation became heavy early but decreased again as soon as bolls were available, was there any extensive development in squares. Records taken during 1931 showed that the development in squares averaged from 26.36 to 26.83 days (Table 15), and it averaged from 32.77 to 33.10 days in bolls (Table 16).

DISPERSAL

With the exception of a few individuals, short-cycle pink bollworm moths rarely fly much above the tops of the cotton plants until the field infestation becomes heavy. For some years prior to the time the study was made, it had been suspected that the moths were capable of voluntary flight for considerable distances or that they were carried along by air currents. A series of closely correlated biological studies, trap plot experiments and statistical analyses have indicated that the moth has a distinct migratory instinct which comes into play under certain conditions. In Texas, these studies were made at Presidio and in the ranch country in and to the north and northeast of the Big Bend district of West Texas. They consisted of (1) daily observations to record moth catch on flight screens, (2) trap plot records and (3) a correlation study of wind movement in the Laguna district of Mexico and field infestation on a large farm in El Paso county.

Flight Screen Data on Moth Dispersal

The flight screen was utilized to determine the period and extent of moth migration. Its construction has been fully described by Fenton and Rude (2). Each screen was set up in the center of a cotton field and observed closely during the period when moth migration was thought to be in progress. The screen, therefore, presented a sticky surface to each of the four cardinal directions so that no matter in what direction a moth was traveling if it came toward the screen, it was trapped.

In each field, weekly records were usually taken of the percentage of boll infestation, number of worms per infested boll and the number of full-size green but unopened bolls per plant, from which the field intensity of infestation could be computed. Also, the comparative moth population in the fields was determined by collecting at night. In the latter case, each field was visited approximately three times a week after dark and 100 net sweeps were made. Data as to relative percentage of humidity, air temperature and wind velocity also were taken at the time the sweepings were made.

Influence of Wind on Flight. Data obtained from flight screens and moth traps indicate that moths travel both with and against mild surface air currents. Records were kept as to wind direction and the side of the flight screen that moths were taken on for several years. These showed that there appeared to be no correlation between moderate surface air currents and direction of moth flight. No automatic wind recording instrument was available, however, that would record all the fluctuations of wind direction over a 24-hour period. Thus, while the prevailing wind might be in one direction, and at the same time moths might be taken on all sides of the screen, it was possible that the wind might actually have blown from all directions at some time during the night. Finally, when an automatic wind recorder was developed which showed an extreme variability of wind direction, it was decided to check our screen records as regards this factor by utilizing some other method for trapping moths. Therefore, revolving moth traps which had been devised by Fulton and Chamberlin (3) in their work with the sugar beet leafhopper, were modified to be suitable for our work and were set up in a heavily-infested cotton field in 1931. One of these traps was so arranged that it always faced the wind, and the other so that it always faced away from the wind. During the season, 28 moths were taken from the trap facing the wind, as compared with 13 from the trap facing down wind.

Trap Plot Data on Moth Flight

While data as obtained from the flight screens were valuable in obtaining information concerning migration, additional indications of the possibility of long-distance dispersal by air were obtained by the trap plot experiments. Each year from 1927 to 1931, a few small trap plots of cotton located in the ranch country to the north and northeast of the Big Bend district have become infested. The general district within which trap plot infestations have been recorded was to the north and nearest to the heavily infested districts in Presidio and Brewster counties, and in the states of Durango and Coahuila, Mexico. The absence of infestation in the many plots which were near lightly-infested districts is also quite striking. As shown in Table 18, few or no moths have been taken on flight screens situated within lightly-infested cotton fields.

During the 4 years when periodic visits to the plots were made to determine when the infestations first appeared, it was found that in the 9 plots infested, 1 was found infested September 30, 5 from October 7 to 29 and 3 from November 3 to 13. These dates correspond closely with the dates moths were being taken on flight screens in the Presidio Valley to the south.

Table 17. Number of pink bollworm moths caught on flight screens compared with average the number taken in night collecting, average percent boll infestation and rainfall, Presidio, 1928-31

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Date screens Set up	Date screens Discontinued
1928								
Total No. of moths caught on 7 screens	-	-	-	21	-	-	July 27	Nov. 15
Av. No. of moths caught per screen per month	-	-	-	3	-	-		
Av. No. of moths caught per night per 100 sweeps	-	-	-	1.23	-	-		
Av. monthly percent boll infestation[1]	-	.11	5.65	40.15	59.96	-		
Rainfall in inches	2.16	0.80	1.88	0.64	1.15	0.41		
1929								
Total No. of moths caught on 5 screens	-	-	1	5	3	-	July 30	Nov. 15
Av. No. of moths caught per screen per month	-	-	0.2	1	0.6	-		
Av. No. of moths caught per night per 100 sweeps	-	-	2.97	3.73	0.25	-		
Av. monthly percent boll infestation[1]	2.00	3.31	22.59	42.59	51.38	-		
Rainfall in inches	1.35	0.62	1.83	1.65	T	0.16		
1930								
Total No. of moths caught on 7 screens[3]	-	-	10[2]	48	10	-	Sept. 15	Nov. 3
Av. No. of moths caught per screen per month	-	-	1.43	6.86	1.43	-		
Av. No. of moths caught per night per 100 sweeps	-	-	2.91	1.66	0	-		
Av. monthly percent boll infestation[1]	2.20	4.08	25.75	59.15	72.48	-		
Rainfall in inches	1.81	1.03	0	3.95	1.11	0.61		
1931								
Total No. of moths caught on 3 "L" screens[3]	-	-	1	66	97	2	Sept. 10	Dec. 4
Av. No. of moths caught per screen per month	-	-	0.33	22	32.33	0.67		
Av. No. of moths caught per night per 100 sweeps	-	-	6.62	3.27	3.67	-		
Av. monthly percent boll infestation[1]	1.54	4.74	32.24	73.29	75.89	-		
Rainfall in inches	0.80	0.96	0.03	0.28	0.70	0.43		

1/ Average for entire district.
2/ Partly in October
3/ One-half actual total.

Table 18. Summary of flight screen data on pink bollworm moth migration according to screen locations, Presidio, 1928-31

Locality	Average per-cent boll infestation 1/	Total number of moths collected from screen	Number of moths collected by sweeps: Totals	Average per night
		1928		
Presidio	33.71	8		
Haciendita	13.00	1	5	0.26
Ochoa	30.86	4	16	0.89
Indio	16.00	0	14	0.74
Adobes	55.86	6	41	5.13
Redford	48.86	1		
		1929		
Presidio	45.57	0		
La Junta	32.07	0	2	0.12
Indio	20.43	0	10	0.71
Ochoa	79.14	0	37	2.18
Adobes	88.91	9	160	10.67
		1930		
Presidio	97.91	13.5	66	4.13
Adobes	84.85	18	13	0.76
Ochoa	96.35	8	38	2.24
Indio	33.94	2		
L. Pelona	21.21	4		
Anthony	28.57	1.5	9	0.64
		1931		
Poole	94.57	49	91	3.79
Gray No. 1	98.71	94.5	210	8.75
Sparks No. 1	41.57	22.5	12	0.50

1/ During period screens were in operation, beginning Sept. 12, ending Nov. 3.

Relation Between Windiness in Mexico and Infestation in the El Paso Valley

Some very suggestive statistical data have been obtained which show an apparent correlation between the wind movement in the Laguna district of Mexico during September and the degree of infestation of cotton on a large farm in El Paso county. With two exceptions, the infestation on this farm increased or decreased each year as the total amount of wind movement in Mexico increased or decreased. The average velocity of wind during September at Tlahualilo was compared with the total number of worms found in 54 man-days of scouting on the farm in El Paso county over a 12-year period, and a striking correlation was found (Table 19). In this table are shown the total wind movement for the month and average wind velocity expressed in kilometers per hour. September was chosen for the correlation study on wind movement because it was during this month that large numbers of moths were migrating. Moreover, while migration did occur after this period, the time element entered in and moths drifting from the Laguna district to the north had less time to produce a generation of larvae before frost than earlier migrants.

The 2 years when no apparent correlation was observed were 1926 and 1930. During the former year, the infestation in the Laguna was comparatively light early owing to availability of water for flooding purposes. This came so late that it was possible to flood fields in cotton rather than land adjacent to them which was intended for cotton the following year, as is usually the case. Because of the heavy flooding of these cotton fields, the winter carryover was greatly reduced and, therefore, the early infestation the following year was likewise much lower than normal. Then about the time the infestation of 1926 began to build up in late summer, a heavy outbreak of leaf worm developed, cotton was defoliated and further late breeding of the pink bollworm greatly reduced. In 1930, there was a heavy mortality of overwintering pink bollworms in the Laguna district. Moreover, only 18,844 hectareas of cotton were under cultivation, which was far below the average cotton acreage for the district. Therefore, while wind conditions were favorable, a comparatively small moth population developed in September that year. The above described conditions during 1926 and 1930 explain the apparent lack of the correlation during these years. In 1931, however, September broke all records for Tlahualilo for windiness and likewise the infestation in the El Paso Valley was the heaviest ever experienced. It is quite likely that the infestation in the Big Bend district has an important bearing on that in the lower El Paso Valley, particularly in Hudspeth county, but the farm where the infestation study was made appears to be too far away from the Big Bend district for infestation by short migratory flight.

Table 19. Comparison of average velocity of wind at Tlahualilo during September and number of worms found in 54 man-days of scouting on the Ivy Dale farm, El Paso county, 1920-31

Year	Total wind movement in kilometers per hour at Tlahualilo	Average velocity per hour	Total number of worms collected
1920	1,526.40	2.12	5
1921	1,785.60	2.48	158
1922	1,094.40	1.52	74
1923	975.60	1.355	0
1924	1,253.95	1.7416	3
1925	1,915.20	2.66	252
1926	1,965.60	2.73	2
1927	1,368.0	1.90	12
1928	1,152	1.60	0
1929	1,130	1.57	0
1930	2,987	4.148	22
1931	3,695	5.13	1,358

Biological Possibility of Long-distance Dispersal

The fact that moths were taken at 3,000 feet above ground level and 6,700 feet above sea level in Mexico by airplane collections led to the speculation of the possibility of these moths being alive and of being able to start an infestation should descending air currents force them once more into the lower air strata near cotton plantings.

Tests showed conclusively that it is biologically possible for females to deposit fertile eggs following mating for the first 24-hour period after they have been isolated from any males or cotton plants for periods of from 1 to 7 days either before or after oviposition had started and held at temperatures of approximately 60° F. Thus, a female might live in the upper air currents for several days at temperatures at or slightly below 60° F., the point at or below which its activity ceases, and then if descending air currents forced it down, start an infestation provided it was able to locate cotton.

HIBERNATION

Date of Appearance of the Long-cycle Larva

At Presidio, winter was passed in the larval stage, such larvae being of the long-cycle type. These long-cycle larvae were developed in the field long before the first hint of cold weather. They were found at Presidio as early as September 16 in open bolls. As the season advanced, the proportion of long-cycle larvae to the total present in open bolls increased until by late October approximately three-fourths of them were of this type. Furthermore, since the number of worms per infested boll increased late in the season, this tended to increase still further the number of long-cycle larvae present in the fields in October and November.

Location of Hibernacula of Long-cycle Larvae

As previously stated, long-cycle larvae may or may not remain within the open bolls. They have been found in cocoons loose in the soil, on the main tap root near the crown and in surface litter. The authors (1) have previously shown that at Presidio in early January, 68.59 percent of all of the live stages were in forms on the plants, 29.23 percent in surface trash and 2.18 percent on the roots or in the soil. The 68.59 percent of stages which were alive and in forms on the plants were those which were in bolls containing non-pickable cotton, in immature bolls and in squares. Obviously many more had been picked with the pickable cotton and taken to the gins. Here, the long-cycle larvae in both single and double seed pass through the gin machinery and are found in the seed pile, which is a very important focal point for winter carryover and distribution of the insect in case the seed are not sterilized. Other long-cycle larvae in double seed which are broken open in the ginning process or which were in the lint are separated from the cotton in the cleaners of the gin and thrown out in the various assortments of gin trash. Thus, the trash pile also is a dangerous potential focal point for carrying over the pest if not sterilized, burned or pulverized in a hammer mill. It is, therefore, apparent that the cotton gin, because of the seed and trash, is one place of winter carryover of larvae and the field the other. With the sterilization of cotton seed at the gin and treatment of the gin trash, the field becomes the main center from which infestation builds up the next year.

Period and Rate of Emergence of Long-cycle Moths

Beginning with the first warm days of late March, long-cycle larvae become active and pupate. After approximately $10\frac{1}{2}$ days spent in the pupal stage (Table 20), the first moths begin to emerge. The period and rate of emergence of these long-cycle moths from 1928 to 1931 is shown in Table 21. Emergence began earlier in 1928 than in any of the other years. The 1928 records are for Castolon, but comparative temperature data show that the climate of this locality is practically identical with that of Presidio. The peaks of the emergence came at different dates in all 4 years, the earliest being April 25, 1928 and the latest June 13, 1930. Generally speaking, the peak of the emergence occurred from late April to early May. The daily curve of moth emergence showed a gradually increasing number of moths emerging each day until the peak was reached, following which a steady decline was observed. An exception to this rule occurred in 1930 when the first peak was reached May 3, following which a fluctuating emergence was recorded which, however, showed a downward trend until the sudden rise to the June peak above mentioned.

Table 20. Duration of pupal period of male and female pink bollworm moths transformed from long-cycle larvae, insectary, Presidio, May 14-June 19, 1931

Males			Females			
Days pupal period	Number of Records	Number of Pupal days	Days pupal period	Number of Records	Number of Pupal days	Mean temperature degrees F.
8	0	0	8	2	16	80.1
9	12	108	9	49	441	82.9
10	82	820	10	93	930	81.7
11	76	836	11	63	693	81.0
12	14	168	12	8	96	80.3
13	5	65	13	5	65	80.3
14	0	0	14	1	14	79.9
Totals	189	1997		221	2255	
Average pupal period		10.57			10.20	

Average mean temperature 81.25° F.

Survival

The comparative survival of the pink bollworm from hibernation at Presidio and Castolon for the period 1928-31 is shown in Table 22. It was highest following the winter of 1928-29, 6.63 percent, and lowest following the winter of 1929-30, 0.97 percent. The average for the 4-year period was 3.39 percent. A comparison of the minimum temperatures recorded during the winters shows the effect of low temperatures on the comparative percentages of survival. Records for 1928 are for Castolon in Brewster county and from 1929 to 1931 for Presidio in Presidio county. The comparative percentages of survival are shown for six combinations of treatments of infested bolls as listed in the table. Each year that the overwinter survival of the pink bollworm was studied, thousands of long-cycle larvae were utilized, being placed in different soils, buried at different depths, placed in various types of cages, etc., but the above combinations of treatments were compared each year. The average survival figures for the total series of hibernation experiments are different than the above but for the sake of better comparison, only the results of the above-mentioned tests are presented.

Table 21. Accumulative emergence of long-cycle pink bollworm moths, Presidio and Castolon, 1928-31

Year	March 31	April	May	June	July	August	Total number: Larvae used	Total number: Moths emerged	Percent survival	Type of cage	Treatment
1928	0.77	66.49	92.27	99.48	100.00	-	5,778	388	6.72	Standard(1 sq. yd.with black cloth cover)	Bolls on surface(dry & irri.) Bolls buried 2" depth)dry & irri.
1929	0	19.20	86.04	97.53	99.57	100.00	93,708	3,244	3.46	Standard; Standard(3 sq. yd.)Standard	4" " " " "; 6" " " " "
1930	0	19.80	64.64	95.77	99.83	100.00	140,540.8	591	0.42	removable cover; Standard; standard(3 sq.yd.)	8" " " " "; Bolls on plants, then buried March
1931	0	24.73	90.53	96.57	100.00	-	222,659	1,573	0.71	White cloth cover	Bolls left on plants,etc.

Table 22. Comparative survival of the pink bollworm in infested cotton bolls under different treatments, Presidio and Castolon, 1928-31

Treatment of infested bolls	Average percent survival in 1928	1929	1930	1931	1928-31
Bolls buried 4 inches Mar. 1-9 irrigated 7 inches Mar. 1-9	11.68	4.01	1.15	0.54	4.35
Bolls buried 4 inches Dec. 6-11 irrigated 7 inches Dec. 7-12	0.31	5.62	1.14	0.07	1.79
Surface bolls, irrigated 7 inches Dec. 5-12	4.36	8.42	0.90	2.42	4.03
Surface bolls not irrigated	2.02	6.55	1.62	4.70	3.72
Bolls buried 4 inches Mar. 1-9 not irrigated	2.96	7.49	0.19	0.00	2.66
Bolls buried 4 inches Dec. 6-11 not irrigated	6.07	7.69	0.84	0.54	3.79
Averages	4.57	6.63	0.97	1.38	3.39
Minimum temperature, degrees F.	19	20	10	18	

CONTROL

As previously stated, in districts where climatic control is insufficient to reduce greatly the wintering population of worms in the field, seed sterilization and gin sanitation do not prevent heavy infestations in cotton fields. At the present time, control of the pink bollworm in growing cotton by the use of insecticides has not proved effective. Experiments were, therefore, conducted for 3 years to determine methods for controlling this insect by various winter and spring cultural practices. These tests included plowing, irrigation, cutting, raking and burning cotton stalks and infested field litter and pasturage.

Cutting and Raking Stalks

From the standpoint of pink bollworm control, the ordinary stalk cutter of the 7 or 9-blade cylinder type was ineffective as it did not cut the stalks at ground surface, shattered off many bolls and cut the stalks into short pieces, all of which made raking for burning difficult. Therefore, this type is not recommended. At present, no type of stalk cutter has been developed that meets all conditions but it is expected that a serviceable type will be perfected soon. For raking, the standard dump rake with closely spaced teeth is the most universal type of rake which may be used. When the last cultivation has left the field fairly level, 4-bar side delivery rakes recently developed by the U. S. Department of Agriculture and now being offered by at least one manufacturer, will probably do the cleaning work better than other rakes.

Burning

Owing to rather high survival of pink bollworms in buried trash in some years and to the fact that cotton is often listed, thus bringing much of the field trash which had been buried nearer to the surface, in cases of severe infestation it appears necessary to cut, rake and burn the stalks and trash before plowing. In rank growths of cotton stalks, or under soil conditions where it was inadvisable or impossible to use a wide-bottom moldboard plow, this aided in complete coverage of all infested trash. Since the burning of stalks and trash is poor practice from the standpoint of soil fertility, this is not recommended except in cases of usually severe infestations or where the plant growth is rank.

Plowing and Irrigation

Three-year' experiments in small plots at Presidio have shown that plowing six inches deep with wide-bottom moldboard plows, 14-inch or more, when equipped with rolling colter, jointers and other special covering devices such as wires, chains or trash shields to aid in trash coverage, covered up the crop remnants and litter of the cotton field containing the wintering stages of the pink bollworm so deeply that few moths escaped the following spring. The disc plow was not as effective as the wide-bottom moldboard plow, but was considerably superior to the narrow-bottom moldboard plow when used at depths greater than six inches. Moldboard-type scraper cleaners, when adjusted as low as possible, improved coverage obtained with disc plows. Shallow plowing, especially when much of the infested litter of the fields was left uncovered or partly covered, gave poor results.

The date of plowing and the time that the fields were irrigated after the plowing were both important factors in securing control. When irrigations were given directly after plowing, December and January were the best months in which to plow. When, however, as is usually the case in farm practice, the irrigations were delayed until March or April, a high survival resulted from plowing during December or January. Plowing in February or March gave decidedly the best results when the irrigations were given in March or April. Therefore, from the practical standpoint, it is recommended to delay plowing the fields as late as possible, at least beyond February 1. Thus, the added benefit of winter mortality of pink bollworms prior to the plowing is obtained and also the interval between the dates of plowing and irrigation is short.

Pasturing

During the winter of 1931-32, the effect of heavy pasturage of cotton fields by goats or cattle on reducing the worm population was studied. While the general appearance of the field after pasturing appeared to show that the goats had cleaned the stalks better than the cattle, counts made before and after the animals were turned in the fields, showed little if any difference. In both cases, slightly better than 94 percent of the worms were killed.

SUMMARY

The pink bollworm is present in the four irrigated cotton growing districts in West Texas and also in a small section of the extreme western limits of the main cotton belt. Low winter temperatures, seed sterilization and gin and oil mill sanitation keep the pest in check in all except the cotton-growing district along the Rio Grande in Presidio and Brewster counties. In these counties, mild winter temperatures, luxuriant vegetative growth of cotton in many fields and proximity to the heavily-infested districts in Mexico, have combined to offset repressive measures as above mentioned so that the pest has increased from year to year and is now causing heavy losses in many fields.

Okra is the only other cultivated plant upon which the pink bollworm can develop and survive the winter in the Big Bend district.

From 1925 to 1931, there has been a steady increase in the percentage of square and boll infestation in the Big Bend district.

The average percentage of infestation was greater over a 4-year period in cotton growing in the heavier silty clay soils than in the lighter sandy or sandy loam soils, in rank heavily-fruited cotton than in stunted, thinly-spaced cotton and in earlier-fruited fields than in those fruiting later.

The damage was caused chiefly by the heavy infestation of green bolls rather than of squares. In addition to the destruction of lint and seed, the quality of pickable lint in heavily-infested fields also was lowered.

The moths remained hidden in cracks in the soil or among surface trash in the cotton fields during the day but became active at dusk, provided temperatures remained at or above 60° F. Activity continued in the fields until dawn provided temperatures continued to be favorable.

The length of life of the moths which emerged before cotton fruited was short, averaging 2.98 days for males and 3.38 days for females when the soil was dry and no water was available. When the soil was dry but water was available, the average longevity for males was 8 days and for females it was 7.25 days. When the soil was watered in varying degrees, the average longevity of the males was 8.88 days and for females it was 10.05 days. After cotton has fruited, the average length of life of the short-cycle male was 11.62 days and the short-cycle female 16.61 days. Lower mean temperatures increased the longevity of the moths.

Most of the moths emerged from the cocoons or pupal cases between 8:00 and 9:00 a.m. The shortest average preoviposition period was found for females from larvae developed in bolls, 2.28 days, while the longest averaged 4.30 days for females developed from long-cycle larvae in seeds of the previous year's crop.

The average duration of the oviposition period ranged from 4.88 days for moths from larvae developed in squares to 7.28 days for moths from larvae developed in bolls.

An average of 111.05 eggs was deposited per each female laying fertile eggs. The average fecundity for such females was 121.61 eggs. The maximum egg deposition recorded for any female was 448 eggs and the maximum fecundity was 451 eggs.

Once oviposition started, the greatest number of eggs was usually deposited on the first night of oviposition. For any large group of females the greatest number of eggs was deposited on the fourth night after emergence from the pupal case or cocoon.

Early in the season before development of mature green bolls in large numbers, the eggs were deposited on various parts of the plant. Later, 88.44 percent were deposited in small groups beneath the involucre of the bolls. Some eggs were laid in the soil.

The average incubation period of the eggs at optimum temperature conditions was 4.6 days. All larvae hatched during the day, rarely before 8:00 a.m. at Presidio.

Unless the young larva found the fruiting part of cotton or a suitable malvaceous plant within 24 to 48 hours after hatching, it died. In cotton squares, the feeding period averaged approximately 10 days, and in bolls, it averaged approximately $16\frac{1}{2}$ days.

Short-cycle larvae and a few long-cycle larvae cut their way out of bolls, while in squares this seldom occurred. In the latter case, the larva was usually in the bloom when it shed. In short-cycle larvae developed in squares, the prepupal period averaged 3.75 days, the pupal period 8.12 days and the total period of development from egg deposition to emergence of the moth averaged 26.60 days. In short-cycle larvae developed in bolls, the prepupal period averaged 3.28 days, the pupal period 8.61 days and the total period of development 32.94 days.

In 1931, six generations developed in squares and three and a partial fourth in bolls.

According to the flight screens, there was a moth migration in the Presidio Valley which occurred chiefly during October in 1928, 1929 and 1930 but extended into November and December in 1931. The migration was comparatively light in 1928 and 1929 but increased considerably in 1930 and in 1931 was the greatest ever recorded at Presidio. Migrating moths traveled both with and against mild surface air currents.

According to trap plot records, the district within which long-distance moth dispersal occurred was fairly well defined and was nearest to the heavily infested fields in the Big Bend district. These trap plots became infested chiefly during October.

Statistical data on a farm in El Paso county where infestation records were made from 1920 to 1931 show, that with two exceptions, the infestation on this farm was correlated with the total amount of wind movement during September in the Laguna district of Mexico, increasing or decreasing as the total amount of wind movement increased or decreased.

Long-cycle larvae were found in open bolls as early as September 16 at Presidio, and as the season advanced, their proportion to the total number present in these bolls increased. Also, since the intensity of the infestation increased, this tended to increase further the number of long-cycle larvae present in open bolls. By late October, approximately three-fourths of the larvae remaining in bolls were of the long-cycle type.

Pupation of the surviving long-cycle larvae began in late March and the first moths emerged after an approximate average pupation period of $10\frac{1}{2}$ days. Long-cycle moths began emerging usually early in April and the peak of their emergence occurred from late April to early May. The emergence was much lighter after early June but in years of heavy survival extended into mid-August.

The average survival for the 4-year period, 1928-31, was 3.39 percent, ranging from 0.97 percent in 1929-30 to 6.63 percent in 1928-29.

With the sterilization of cotton seed at the gin and treatment of the gin trash, the cotton field remained as the main center from which infestation built up the next year. In cases of severe infestation, it was found that best results in obtaining a reduction in pink bollworm infestation the following year were obtained by cutting, raking and burning stalks and infested litter in the field. Also, in rank growths of cotton stalks, or under soil conditions where it was inadvisable or impossible to use wide moldboard plows, it was found that the above operations aided in obtaining complete coverage of all the remaining trash in the field. Mowers equipped with brush-type cutter bars were the most effective in cutting stalks at ground surface and in reducing shattering of bolls. The ordinary stalk cutter of the 7 or 9-blade cylinder type was very ineffective.

Of three types of plows tested, the wide-bottom moldboard plows, 14-inch or more, gave the best trash coverage, then disc plows, while the poorest type were the narrow-bottom moldboard plows. Trash coverage by moldboard plows was improved when they were equipped with rolling colters, jointers and other special covering devices such as wires, chains or trash shields. Moldboard-type scraper cleaners, when adjusted as low as possible, improved coverage obtained with disc plows.

Plowing six inches deep gave better results in pink bollworm control than the shallower depths, and shallow plowing with much of the infested litter of the fields left partly or entirely uncovered gave very poor control.

When possible to apply irrigations immediately after plowing, that done in December or January was very effective. When the irrigations of such plowed fields were delayed until March or April, control was very poor. Plowing in February or March gave decidedly the best results when irrigations were given in March or April.

Heavy pasturing of infested fields during the winter by either goats or cattle was very effective and killed over 94 percent of the wintering stages.

LITERATURE CITED

(1) Fenton, F. A. and Owen, W. L.
1931. Hibernation of Pectinophora gossypiella in Texas. Jour. Ec. Ent. vol. 24. No. 6, pp. 1197-1207.

(2) Fenton, F. A. and Rude, C. S.
1932. Dispersal of the Pink Bollworm by Flight and Wind Carriage of the Moths. (Manuscript submitted for publication).

(3) Fulton, F. A. and Chamberlin, J. C.
1931. A New Automatic Insect Trap for the Study of Insect Dispersion and Flight Association. Jour. Ec. Ent. Vol. 24, No. 3, pp. 757-761.

(4) Gough, L. H.
1919. On the Effects Produced by the Attacks of the Pink Bollworm on the Yield of Cotton Seed and Lint in Egypt. Bull. Ent. Res. London. IX, No. 4, pp. 292-296.

(5) Hunter, W. D.
1926. The Pink Bollworm with Special Reference to Steps Taken by the Department of Agriculture to Prevent its Establishment in the United States. U. S. Dept. Agr. Bull. No. 1397, 30 pp., 11 figs.

(6) Loftin, U. C., McKinney, K. B. and Hanson, W. K.
1921. Report on Investigations of the Pink Bollworm of Cotton in Mexico. U. S. Dept. Agr. Bull. No. 918. 64 pp., 11 figs.

(7) Ohlendorf, W.
1926. Studies of the Pink Bollworm in Mexico. U. S. Dept. Agr. Bull. No. 1374. 64 pp., 15 figs.

(8) Owen, W. L. and Calhoun, S. L.
1932. Biology of the Pink Bollworm at Presidio, Texas. Jour. Ec. Ent. Vol. 25, No. 4, pp. 746-751.

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