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REPORT ON INVESTIGATIONS OF THE PINK BOLLWORM[1] OF COTTON IN MEXICO.

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CONTENTS.

THE LAGUNA DISTRICT.

In 1918 the Federal Horticultural Board deemed it advisable to establish a research station in a locality where there was a sufficient infestation of the pink bollworm to make possible the gathering of detailed information regarding this serious cotton pest. This research station was established in February, 1918, in Ciudad Lerdo, Durango, Mexico, near Torreon. Approximately 95 per cent of the upland cotton produced in the Republic of Mexico is grown in this vicinity, the so-called Laguna district.

[1] *Pectinophora gossypiella* Saunders: Order Lepidoptera, family Gelechiidae.

[2] This report is based on two years' work in the Laguna, conducted by the Federal Horticultural Board under authority given, in the appropriation for the eradication of the pink bollworm, to investigate in Mexico or elsewhere the pink bollworm as a basis for control measures. The experts conducting this investigation were transferred to the Board for this purpose from the Bureau of Entomology and this paper is therefore offered for publication as a joint contribution from these two offices. Provision for the establishment of the laboratory in Mexico and authority for the work was obtained through the courtesy of Senor Pastor Rouix, Secretary of Agriculture of Mexico. The work was made possible also by the active cooperation and assistance of the cotton planters of the Laguna. Special thanks are extended to the Tlahualilo Company, the Testamentaria de Carlos Gonzales, and to Mr. Lloyd Rone for the use of their plantations for experimental purposes and many other courtesies. This station was established during 1918 under the general field direction of Mr. August Busck and was continued by the authors of this paper under the general direction of the chairman of the Board and Dr. W. D. Hunter.

The Laguna district is an irregularly shaped valley of about 2,000 square miles, almost completely surrounded by mountains. It is situated about 250 miles south of the Rio Grande, on the boundary line of the States of Durango and Coahuila, Mexico. It derives its name from the fact that it was formerly a lake (laguna) serving as an outlet of the Rio Nazas. As recently as 1837 a part of the Tlahualilo property was under water and at present there are considerable areas near San Pedro, Coahuila, which are filled with water when the river is at a flood stage. The soil is a deep alluvial deposit, very rich, and well adapted to the culture of cotton.

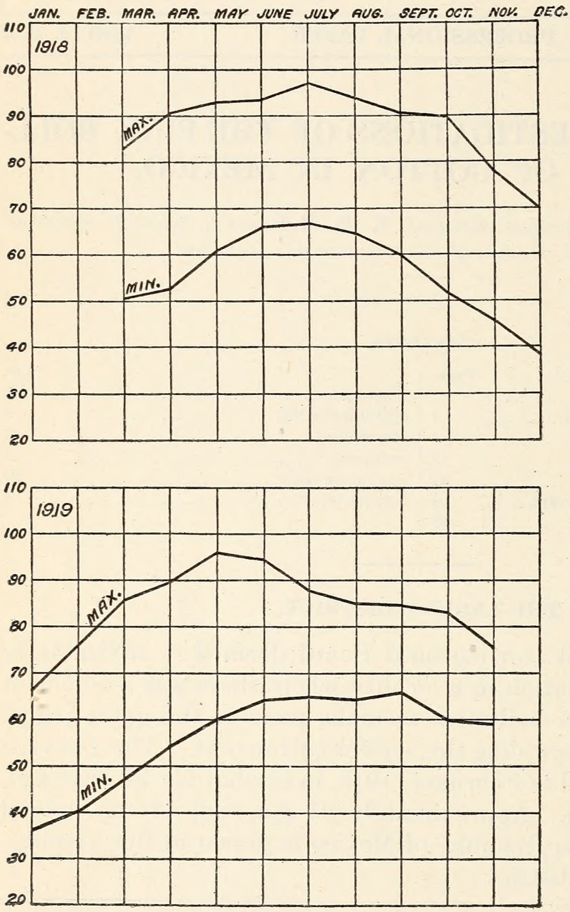


FIG. 1.—Average mean temperature for 1918 and 1919 at Ciudad Lerdo, Durango, Mexico.

CLIMATIC CONDITIONS.

Torreon, the principal city of the Laguna, has an elevation of about 4,000 feet. Generally speaking, this section of the country receives an average of 6 to 8 inches rainfall annually, but in 1919 the precipitation was very close to 15 inches.

In the months of May, June, July, and August temperatures range from 95° to 100° F. during the day down to about 64° (average) at night. In the winter months of December, January, and February the thermometer registers from 69° (average maximum) to as low as 24° F.

Figure 1 gives a graphic record of the thermometer readings taken at the station in Ciudad Lerdo, Durango.

It must be kept in mind that the above charts represent the average of the daily readings for each month and not the extremes which were reached. The relative humidity is rather high, often reaching the saturation point at night.

From monthly records kept by the Tlahualilo Co., at Tlahualilo, Durango, covering a period of 15 years extending from 1904 to 1918, inclusive, the average rainfall for that region has been 8.07 inches per year.

TABLE I.—*Annual precipitation in inches at Tlahualilo.*

Year.	Precipitation.	Year.	Precipitation.	Year.	Precipitation.
1904	6.09	1909	13.32	1914	11.42
1905	11.31	1910	3.91	1915	4.63
1906	12.09	1911	6.98	1916	4.30
1907	8.71	1912	8.56	1917	3.46
1908	6.43	1913	12.79	1918	7.14

From records taken at the laboratory in Ciudad Lerdo, the following figures are given, covering the years 1918 and 1919, the years during which the observations relating to the pink bollworm in this report were made.

TABLE II.—*Monthly precipitation in inches at Ciudad Lerdo, Durango.*

Month.	Precipitation.	
	1918	1919
January	(1)	1.20
February	(1)	Trace
March	0.35	0.54
April	Trace.	0.00
May	0.02	0.00
June	2.76	1.44
July	Trace.	3.98
August	1.56	5.16
September	0.07	1.75
October	0.09	0.87
November	1.74	0.15
December	0.21	(2) 0.00
Total	6.80	15.09

[1] No record. [2] Record only for Dec. 1–10.

CULTURAL METHODS AND PRODUCTION.

This section is semiarid and depends upon the water from the Rio Nazas and Rio Agua Naval for irrigation. The water usually comes down some time between August and December and is applied at a rate which is equivalent to about 1 meter deep to the fields that are to be planted in the following year. With an occasional rain in June or July or a small amount of water from the river during these months the fall irrigation suffices for the crop. As there is not enough water for all the land, only a small portion is cultivated, and on some plantations a portion of the land regularly lies fallow for several years at a time. Under this system of cultivation the land has to be well prepared and thoroughly cultivated in order to conserve the moisture. The cotton planting begins about February 15 and may continue until June if there are June rains or water in the river. The land is planted as soon as possible after it dries out, as this is necessary to secure germination.

Cotton is the principal crop grown in this section, and while there are small areas devoted to corn, wheat, beans, and alfalfa, most of the planters use their land year after year for cotton and buy the feed for their domestic animals elsewhere. No very reliable data are available on acreage and production in the Laguna, but the annual production varies from 60,000 to 150,000 bales, with an average crop of from 75,000 to 80,000 bales. The yield varies from one-fourth bale to 2 bales per acre, with an average of from one-half to three-fourths of a bale. All of the cotton is of the short-stapled varieties, as it has been found by experience that these give better results than the long-staple or Egyptian varieties.

DISTRIBUTION OF THE PINK BOLLWORM.

The species is widely distributed throughout the cotton-producing world, and according to Gough (*12*)[3] is now known to occur in India, Palestine, Mesopotamia, Ceylon, Burma, Straits Settlements, China, Japan, the Philippine and Hawaiian Islands, East Africa, Zanzibar, Egypt, Sudan, West Africa (Southern Nigeria, Sierra Leone), Brazil, Mexico, and Texas in the United States. It has more recently been found in a limited area in western Louisiana adjoining the infestation in eastern Texas.

INTRODUCTION INTO MEXICO.

The pink bollworm was introduced into Mexico in 1911. During that season two importations of Egyptian seed were made. One consisted of 125 sacks and was planted near Monterey, in the State of Nuevo Leon. The other, consisting of 6 tons, was planted near San Pedro, State of Coahuila, in the Laguna district. From what is known of the abundance of the pink bollworm in Egypt in 1911 it is probable that both shipments of seed were infested and that both of them contributed to the present infestation in Mexico. Cotton culture has not been continued in the vicinity of Monterey, but the crop of Egyptian cotton produced there in 1911 attracted considerable attention and much of the seed was shipped to the Laguna.

At the present time the pink bollworm is generally and uniformly distributed in the Laguna.

PRESENT DISTRIBUTION IN MEXICO.

Outside of the Laguna district the pink bollworm is known to be established in three localities in Mexico. One of these is at Santa

[3] Italic numbers in parentheses refer to "Literature cited," p. 57.

Rosalia, State of Chihuahua, at a point about 200 miles south of El Paso. The other two infestations are located in the northern portion of the State of Coahuila. One of these is at San Carlos, at a point about 15 miles southwest of the town of Jimenez on the Rio Grande, or about 40 miles approximately west of Eagle Pass. At this place infestation has been found in fields in the immediate vicinity of the gin. None of the insects were found in outlying fields. The other infestation in the State of Coahuila is located at Allende. This is about 40 miles from the nearest point on the Rio Grande.

During the season of 1919 inspections were made by agents of the Federal Horticultural Board in the cotton region between Matamoras and Nuevo Laredo. No traces of infestation were found. Likewise the cotton growing in the Imperial Valley in the State of Lower California has been inspected with negative results. Inspection of these regions will be continued, as the insect may at any time become established along the Rio Grande by shipments of seed from the interior of Mexico.

The remarks above refer to infestations in growing cotton. The pest is frequently brought to the border towns of Mexico in cotton seed scattered in freight cars, and living specimens are constantly being found under such conditions by the inspectors of the Federal Horticultural Board.

LIFE HISTORY.

SUMMARY OF LIFE CYCLE.

The moths of the pink bollworm emerge in the early spring and summer from larvæ which have passed the winter in cotton seed or bolls. The eggs are laid soon after emergence on almost any part of the plant. The incubation period is from 3 to 12 days and the larvæ begin feeding in the squares or bolls. During the spring and summer the larval period occupies from 8 to 16 days, but in the fall and winter it is extended over a period of from a few months to two years or more. These two kinds of larvæ, while indistinguishable taxonomically, may be designated short-cycle or "summer" larvæ and long-cycle or "resting" larvæ. Pupation takes place in the soil or trash on the surface of the soil, in the summer stage, and in the ground, seed, or lint in the resting larvæ. The pupal period covers from 6 to 20 days. The average length of the life cycle from egg to egg during the summer is 31 days.

LABORATORY METHODS.

The experiments with the life history of the pink bollworm were all conducted at Ciudad Lerdo, Durango, Mexico. An adobe house was used for a laboratory. The adults were confined in 2-quart fruit jars covered with cheesecloth for oviposition. Branches of cotton plants containing leaves and squares, stuck in tubes of water to keep them fresh, and bolls were provided for oviposition. Pieces of blotting paper dampened with water or sweetened substances were added as food for the moths. The eggs were removed to other jars for hatching and the young larvæ carefully removed to the food. Bolls and squares were used, but the squares were found more satisfactory. The food with the young larvæ was placed in vials plugged with cotton. The pieces of bolls would become discolored, decomposed, and unsuitable for food in one or two days, while a square would remain in good condition several days and the larva could be examined daily with less disturbance.

Wire cages were also used over small potted plants and cotton plants in the experimental plat to check the laboratory results. The pupæ were removed to glass vials with a piece of damp cotton in the bottom to provide the necessary humidity.

Temperature and humidity records were made with maximum and minimum thermometers and recording hygrothermographs placed indoors and outside in a U. S. Weather Bureau instrument shelter.

MOTH.

Description.

The moth with wings spread is about three-fifths of an inch from tip to tip, dark brown in color, with irregular blackish markings on the forewings, the hindwings silvery gray with no distinct markings. The forewings are bluntly pointed, the hindwings acutely pointed, and both heavily fringed posteriorly. When at rest the wings are folded flat over the back.

Habits.

The moths are very seclusive in their habits during the day. It is exceptionally rare to find one in the fields until after sundown. Just at dusk they can be seen flitting very quickly from plant to plant, and by close examinations with a flashlight at night they can be readily found in a resting position on almost any part of the plant. They are active as late as 12 p. m. No observations were ever made later at night, but it is very likely that they remain active until daybreak. Occasionally they conceal themselves on the plant, but usually they crawl under trash, stones, clods, or even into the loose soil. They are very loath to leave their hiding places during the day, but when disturbed they run with a quick jerky movement or fly a short distance and immediately hide under the nearest object.

In the laboratory the moths emerging from stored cotton would congregate on the window screens at dusk. They would remain quietly till morning and then return to their hiding places. Only rarely would one be seen during the day.

LONGEVITY.

Males and females are produced in about equal proportions and their length of life is about equal. Under favorable laboratory conditions one moth was kept alive for 26 days, but the average length of life of the adult was 14.7 days. There are no indications that moths ever live for long periods of time or pass the winter in this stage.

Whether moths under natural conditions ever take nourishment other than water was never observed, but just as many eggs were deposited in the breeding jars where pure water was used as where sweetened water was substituted. Water is a very essential factor in the longevity of the adult. The average length of life of the moths where no water could be obtained was 7.6 days, compared to 14.7 days when water was supplied daily.

PREOVIPOSITION PERIOD.

Eggs were deposited in captivity from 1 to 6 days after issuance of the moth, with an average of 3.8 days preoviposition period. It is not known how long a period elapses before oviposition begins in nature, but from analogy with other species it is possible that the bulk of the eggs are laid the first night under normal field conditions. The moths were never observed in the act of depositing eggs, either in the fields or in the breeding cages, but from the night-flying habits of the moth it is evident that oviposition takes place at dusk or at night.

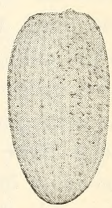


FIG. 2.—Egg of *Pectinophora gossypiella*. Highly magnified.

EGG.

DESCRIPTION.

The egg is 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 greenish tint when first deposited, turning to almost red before hatching; surface finely reticulated with regular longitudinal lines or ridges with irregular cross-connections, resembling the reticulations on the hull of a peanut. (Fig. 2.) The larva can be easily seen inside the shell just prior to hatching.

POSITION ON PLANT.

The eggs are deposited on all parts of the plant, including the bolls and bracts, leaf buds, leaves, stems, and squares. The preference is for some more or less hidden location, such as the base of the boll, between the bracts and bolls, the folds of the small leaf buds, the creases formed by the veins and midribs of the leaves, and the axils of the leaves.

Some heavily infested plants were examined at Lerdo during August and September, 1919, to determine the proportion of eggs deposited on different parts of the plants, the results of which are given in Table III.

TABLE III.—*Location on the cotton plant of the eggs of P. gossypiella.*

Number of plants examined.	Number and location of eggs.							Total number of eggs on plant.
	Leaves.	Stems.	Buds.	Squares.	Bolls.			
					Bracts.	Base.	Tip.	
1	7	6	45	1	8	81	0	148
1	32	6	107	3	11	108	3	270
1	21	36	34	0	74	87	0	253
1	94	36	66	2	54	53	1	315
1	31	24	37	3	78	49	1	223
1	20	16	56	1	93	55	2	243
1	22	15	17	3	2	39	0	98
Total (7 plants).	227	139	362	13	320	472	7	1,549
Per cent	14.7	9.0	23.4	0.8	20.7	30.5	0.5	....

It is clearly seen that the boll is the most favored place, 51.7 per cent of the entire number of eggs being deposited on the boll and its appendages. The small leaf buds were second with 23.4 per cent, the leaves third with 14.7 per cent, the stems fourth with 9 per cent, and the squares fifth with only 0.8 per cent. It is further seen from this table that the base of the boll is frequently selected, as 30.5 per cent of the eggs were deposited there and only 0.5 per cent were deposited in the sutures at the tip of the boll. The position of the eggs upon the plant is important, for upon it largely depends the fate of the young larvæ. It is essential that the larvæ reach the squares or bolls to feed, as no larvæ were ever found which had developed beyond the second instar on other parts of the plant. It is a mistaken instinct of the moths to oviposit in other parts of the plant, as it is evident that a much larger proportion of the larvæ hatching from eggs laid in close proximity to the food will reach it than of those that have to crawl over the plant exposed to their natural enemies in search of food.

When laid on the leaves, buds, stems, and squares the eggs are usually placed singly or in small groups of from 5 to 10. When laid on the tip of the boll they are placed singly or in small groups in the sutures. In this position the eggs are often flattened or crushed by the growing of the boll. When laid at the base of the boll they are placed between the calyx and the boll or beneath the bracts around the base of the boll, and are usually in masses of from a few to as many as 75 to 100, which are overlapped and flattened out more or less shingle fashion. The flattened appearance in this case is due to the presence of the calyx and not to the natural shape of the egg. In these masses, eggs of all stages of development, as well as shells, are found, showing that they were not all deposited at one time by a single female.

As the female does not deposit eggs readily in captivity, difficulty was experienced in determining exactly how many eggs were deposited by a single female. In our experiment usually from 5 to 20 moths were confined in one cage. Under these conditions it was never known which moths had oviposited and which had not, and while several hundred eggs were often obtained from a cage, it is certain that the maximum number they were capable of laying were never obtained. Often heavy, pregnant females were found dead in the cage and apparently never had deposited any eggs. Upon dissection of gravid females the ovaries were found to contain from 75 to 125 well-developed eggs. Busck (*8*) places the number at over a hundred and Willcocks (*7*) says that while small individuals may produce only about 250 eggs, well-developed individuals are capable of laying 400 to 500 eggs or more.

Incubation.

All of our records were made under laboratory conditions. Figure 3 shows that the difference between the maximum and the minimum, or the day and night temperatures, for each month amounts only to from 6° to 8° F.

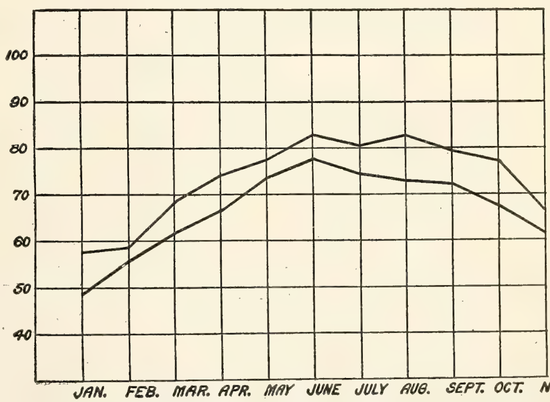


Fig. 3.—Average mean maximum and average mean minimum temperatures for 1919 at Ciudad Lerdo, Durango, Mexico.

The egg stage, even under these rather constant conditions, varied from 3 to 12 days. The range for the months of April, May, September, and October was from 7 to 12 days, and for June, July, and August it was from 3 to 5 days, with an average of 4.6 days for the entire season, the average being taken from 300 records based on thousands of eggs.

Hatching.

The actual hatching of the egg requires only a very short time. The young larva can be seen moving inside the shell a short time before it actually emerges. An opening is cut in the broad end of the egg and the small larva wriggles out and crawls rapidly away in search of food.

The empty shell is white and soon becomes an almost unrecognizable wrinkled object. It remains on the plant until it decays or is carried away by the wind or other agencies.

LARVA.

Newly-Hatched Larvæ.

The newly-hatched larvæ are creamy white, with dark-brown head and thoracic shield and long, prominent, dark setæ showing very plainly. They are a little less than 1 mm. in length and gradually taper from the head, having thus a slight wedge-shaped appearance. In this stage the larvæ are very active. Under laboratory conditions they are very restless and crawl rapidly from place to place before entering a square or boll. Many larvæ continue crawling around for 24 hours or more until they become so weakened that they are not able to cut their way into the squares or bolls. It was often observed that most of the larvæ which succeeded in entering the food provided for them did so the day they were hatched. It is not known to what extent this wandering around takes place under natural conditions. Larvæ are found crawling over the plants, but they always seem restless and ill at ease. This probably does not take place normally to any great degree, except in the case of larvæ from eggs laid on other parts of the plant than the squares and bolls.

Larvæ Entering Bolls.

The larvæ do not seem to have any preference as to where the boll is entered. Sometimes a light netlike web is spun and the entrance is made underneath it. At other times the entrance is made with no protection whatever. The larvæ cut the carpel away, throwing the fragments outside, very little if any being consumed. The time required for the larvæ to enter may vary with the age of the boll, but it usually takes them from 20 to 40 minutes to become completely hidden. If the boll is examined soon after they have entered, the holes are easily located by the surrounding frass, and although minute, can be seen with the naked eye. After 2 or 3 days the frass is blown away by the wind or removed by other agents and the holes close up, leaving only brownish spots which are hard to differentiate from other discolorations on the boll. Then they can only be detected by a trained eye, and the only way to be certain a boll is infested is to examine its interior.

Larvæ After Entering Bolls.

After the boll has been entered the larvæ become glassy white, soft, and sluggish. They so closely resemble the watery lint at this stage that they would be very easily overlooked, except for their dark heads and thoracic shields, which show as black specks against the lint.

There are three molts, completing four larval instars or stages. The first stage lasts about 2 days; the second and third, 3 to 4 days each; and the fourth, 4 to 5 days,; thus the larval development is completed in an average of 13.3 days in the summer larvæ. The second and third instars resemble the first in general appearance, and it is usually in the fourth or last larval stage that the larvæ change to the characteristic pink color from which the name "pink bollworm" is derived. Sometimes the pink color appears in the third instar, especially if development has been retarded in some way or the larva has been exposed to the air. The coloring first appears as transverse pink lines on the dorsal side of the segments and diffuses and deepens till there is only a small whitish or flesh-colored line left between the segments. The color seems to be more pronounced in the larvæ which reach maturity in the late summer or early autumn and is a very deep pink or dull red. The head and thoracic shield are reddish brown with dark-brown mandibles and anal plate. The ventral side, legs, and prolegs are white to flesh colored, the legs and prolegs with brownish claws and crotches. The full-grown larva is cylindrical and measures about one-half inch in length.

With the fourth stage the larva becomes very active again when disturbed and conceals itself as quickly as possible. A cocoon is spun attached to whatever object the larva is hiding in. The full-grown larva is never content outside a cocoon after it leaves a boll or seed. If it is taken from one cocoon it will immediately make another. How many times this will be repeated was not determined, but a perfectly healthy larva is rarely if ever found outside a cocoon, except when crawling from place to place.

PUPA.

The pupa is whitish, with faint markings of pink when first formed, turning to a mahogany brown as it dries and to a darker brown before emergence. It measures 8 to 10 mm. in length by 2.5 to 3 mm. in width. The surface is covered with a fine velvety pubescence, the posterior end terminating in a short, stout, upwardly pointing, hooklike process.

Pupation of Summer Larvæ.

When the summer larvæ have completed their feeding, they cut to the outside of the boll directly through the carpel wall from the last seed attacked and drop to the ground for pupation.

This exit hole through the carpel wall is usually round and clean cut and can be easily recognized as having been cut from the inside of the boll. Plate II, A, gives a comparison of the entrance hole into the boll of the common bollworm, *Chloridea obsoleta* Fab., and the exit hole of the pink bollworm. The entrance holes of the common bollworm are larger, not so clean cut, and surrounded by a raised margin. They are not likely to be confused once both have been seen.

In the case of the summer larvæ, the holes made in the green cotton boll are always for the exit of the larvæ, and not for the issuance of the moth. From an examination in 1919 of over 16,000 green bolls that averaged over 2.5 larvæ per boll, not a single pupa or pupal skin was found. Should a larva cut a hole in a green growing boll for the issuance of the moth, this hole would probably close from proliferation before the pupal stage of 9.3 days is passed.

Occasionally, in mature or dry bolls, as distinguished from green ones, more than a mere exit hole is cut when the larva reaches the carpel wall. The carpel tissues and the adjoining lint are cut away and an elongate pocketlike cavity is made large enough for the larva to become straightened out in its final preparation for pupation. When this is done a light cocoon is spun inside this cavity and a hole cut through the carpel wall to the outside. The last remaining parts of the carpel wall are not cut entirely out leaving an open hole, but the particles are held together and in place by a few fine strands of silk which are easily broken and pushed away when the moth emerges.

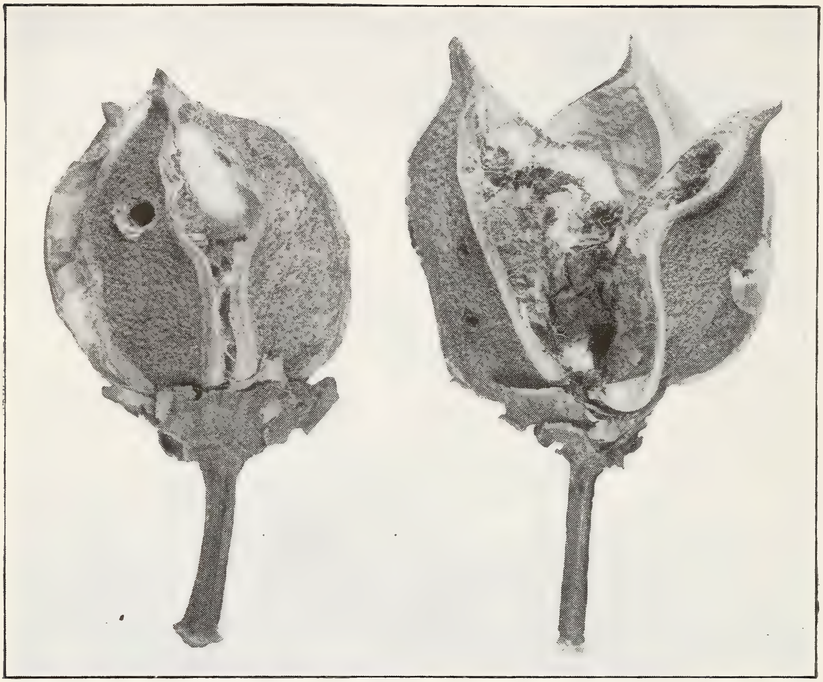
The very fact that only a few larvæ pupate in the bolls is conclusive enough that there are other more favorable places for pupation. These places are either on the ground or in the ground. If the moisture conditions are sufficient on the surface, they may spin a cocoon in the trash or on any convenient object, and pupate there; but if it is too dry and the soil is loose they may burrow as deep as 3 inches below the surface, make an earthern cell, line it with a very fine, tough cocoon, and pupate there. During the summer a good many pupæ are probably destroyed by cultivation, but when pupation takes place in the ground, only the exit passage being destroyed and the pupa itself not molested, the moth may be able to escape because of its burrowing power.

Fullaway (*3*) and Busck (*8*) found that in Hawaii pupation normally takes place in the boll and only rarely in the soil or other places. Maxwell-Lefroy (*2*) found that in India pupation occurs in the boll or on the bracts or leaves of the cotton, and in unirrigated black cotton soil might be found in a crack of the dry soil. Willcocks (*7, p. 113*) says that in Egypt—

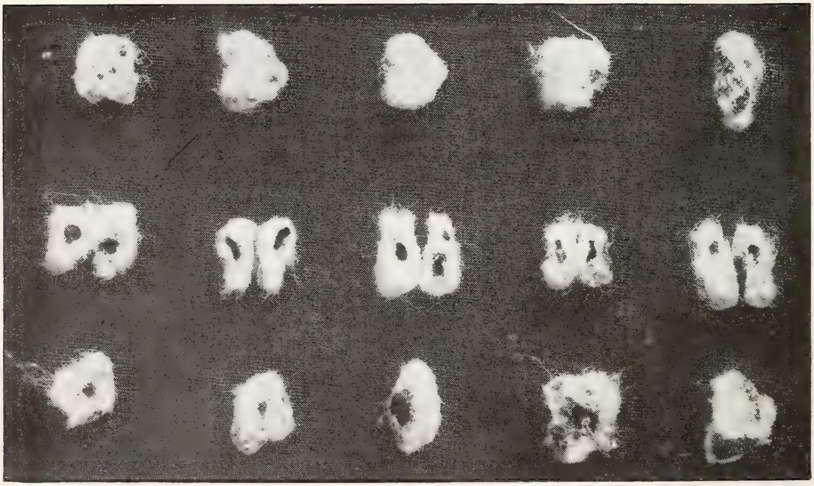
> Pupation seems most often to take place on the ground under the fallen leaves, or in the fold of a dead leaf or again between two dead leaves, also on old bolls which have dropped or been broken off, and under or attached to small lumps of earth. In fact they may be looked for amongst any shelter of this kind. One situation was noted that seems to be especially favored by the larvæ as a haven to pass the pupal stage, this was furnished by the dead flowers which are of course very numerous below the plants.

In Mexico pupæ were never found on the leaves or bracts under field conditions. When green bolls were picked and left in sacks the emerging larvæ would sometimes hollow out a slight depression and pupate near the base of the boll, or they would pupate between the involucre and boll without making a depression, or spin their cocoons

COTTON BOLLS SHOWING CHARACTERISTIC INJURY BY THE PINK BOLLWORM.



A, On left, entrance hole of *Chloridea obsoleta*. On right, exit holes of pink bollworm. (Hunter.)



B, Double seed formed by pink bollworm larvae: Above, holes made for issuance of moth; middle, broken apart to show cavities; below, double seed intact.

PINK BOLLWORM.

on the sides of the sack. The old flowers under the plants did not seem to be more favored than other bits of rubbish.

The duration of the pupal stage of summer larvæ from 150 records ranges from 6 to 14 days. There is considerable variation among the individual pupæ, some requiring 1 to 2 days more than others which pupated on the same night.

Table IV summarizes over 300 complete records of the various stages of the pink bollworm at Lerdo, Durango, Mexico, during 1918 and 1919.

TABLE IV.—*Duration in days of summer stages of P. gossypiella.*

	Average
Egg stage	4.6
Larval instars:	
First	2–3
Second	3–4
Third	3–4
Fourth	4–5
Total average	13.3
Pupal stage	9.3
Preoviposition period	3.8
Total period from egg to egg	31.0

RESTING LARVÆ.

In the preceding part the development of the different summer stages of the pink bollworm has been discussed. There is still another important phase of the life history—the long-cycle or resting larvæ. It is in this stage that the species passes the winter when no food is available or when conditions are adverse in any way. It is also in this stage that the greatest dispersal by man takes place and only in this stage that any known control measures can be used.

Beginning some time in August, when the temperature is still high and there is yet plenty of food available, some of the larvæ upon reaching maturity do not pupate at once, but remain wherever they are as full-fed larvæ. These larvæ are identical in form with those that pupate and can not be distinguished from them. What causes some larvæ to do this and others to pupate as usual when reared under the same conditions is not known, but Willcocks (7) suggests it is probably some instinct inherited from the time when in its original natural habitat there were no food plants available to sustain the species over a long period of time. In November and December, when the temperature is lower and no food is available, all of the larvæ develop this tendency and it is the exception rather than the rule for them to pupate. Thus in the Laguna this resting habit seems to be a combination of estivation and hibernation, for it begins while food is still available and the temperature high. In this section the average frost date is about November 20, and moths emerging after this date would as a rule find no suitable places for oviposition.

When a larva prepares to go into the resting stage it remains in the boll in which it has been feeding. Usually a tough, heavy cocoon is spun either in the lint, in a single seed, or two seeds are fastened together to form a "double seed." (Pl. II, B.) The double seed is formed by eating away part or all of the contents of the two adjoining seeds and spinning a strong continuous cocoon inside the cavities of the two seeds, which holds them firmly together and makes them difficult to separate.

Part of these seeds go through the gin and come out intact, and finding double seed is sure evidence of pink-bollworm infestation.

Often double seeds are formed in seed in different locks, the connecting cocoon running through the hole made in the partition wall. This affords good protection for the larva, as it prevents the seed from falling to the ground and being exposed to excessive moisture and other agencies which are more detrimental to the larva on the ground than on the plants.

When the cocoon is spun in the lint or a single seed the larva lies in a curled-up position and the cocoon is spun tightly around it, forming a spherical compact mass. Similar cocoons are formed in the ground or attached to any convenient object if larvæ are removed from seed or lint. The cocoon fits so closely and is so tough that it is very difficult to remove without injuring the larva. It is very hard to detect a larva inside a seed, and the only sure way to tell whether the seed contains a larva is to examine the interior. Willcocks (7) in writing about Egyptian cotton seed, which has a smooth, black coat and is not covered with lint, says the silken-covered entrance hole can usually be seen with a lens. This, however, does not hold true for short-staple seed.

Few data are available on the number and proportion of larvæ found in the lint and in the single and double seed. Samples of cotton were hand-ginned and the number of larvæ in single and double seed determined, but unfortunately no record was kept of the number in the lint. It is possible that some of the larvæ counted as in single seeds in the first and second picking samples were in the lint, but this did not occur in the samples of the third picking. It will be noted that the sample for the third picking is from the 1918 crop and had been stored for some time. At the time of examination a considerable part of the larvæ were dead, but this does not affect the proportion found in the single and double seed, and while the figures are not quite comparable, they at least give an idea of the number of larvæ present at different times. The number of larvæ found in the single and double seed for the different picks are given in Table V.

TABLE V.—*Number of pink bollworm larvæ found in single and double seed of cotton picked at different dates.*

Weight of sample.	Date picked.	Date examined.	Double seed.			Single seed.		
			Number double seed.	Number of larvæ in double seed.	Per cent of total larvæ in double seed.	Number single seed damaged.	Number of larvæ in single seed.	Per cent of total larvæ in single seed.
First picking:	1919.	1919.						
½ pound	Aug. 4	Oct. 10	0	0	0	38	2	100
1 pound	Aug. 6	Oct. 8	[1] 0	0	0	108	1	100
1 pound	Sept. 23	Oct. 22	0	0	0	156	3	100
Second picking:								
½ pound	Oct. 16	Oct. —	30	29	58	121	21	41
1 pound	Nov. 2	Oct. —	[2] 34	30	56.6	467	23	43.4
Third picking:	1918.							
½ pound	Dec. 3	Mar. 30	106	95	30	715	250	70
¼ pound	Dec. 10	Mar. 20	36	26	33	597	53	67

[1] One pupa in lint, not counted in above.
[2] Two pupæ in lint, not counted in above.

This table shows that no double seed was found in cotton from the first picking, that 57.3 per cent of the larvæ were found in double seed from the second picking, and that the percentage fell to 31.5 in the third picking. It is probable, however, that occasional double seeds are formed during August and September or in the first picking.

Taking an average of these figures and reducing them to a 1-pound basis, the number of larvæ per bale present in the seed from the different pickings can be calculated. It is thought that no live larvæ pass through the gins in the lint, and that many of the larvæ in the seed are driven out during the cleaning and ginning. It is certain that the large number found in seed when hand-ginned were never found in commercially ginned seed.

TABLE VI.—*Number of pink bollworm larvæ found per pound and the estimated number per bale in cotton from different pickings.*

Weight of sample.	Double seed.				Single seed.				
	Number double seed.	Number larvæ in double seed.	Estimated number of larvæ per bale in double seed.	Per cent of total larvæ in double seed.	Number single seed damaged.	Number larvæ in single seed.	Estimated number of larvæ per bale in single seed.	Per cent of total larvæ in single. seed.	Estimated number of larvæ per bale in single and double seed.
First picking: 1 pound	0	0	0	0	121	6	9,000	100	9,000
Second picking: 1 pound	43	39	58,500	56.5	392	30	45,000	43.5	103,500
Third picking: 1 pound	189	161	241,500	28.5	1,749	404	606,000	71.5	847,500

Gough (*5*), in one of his earlier publications, states that there are two generations of the hibernating larvæ, the older generation consisting of full-fed worms and the younger the winter-feeding brood, which were not full-fed at the time of hibernation and continue developing slowly till about March. In a later publication (*12*) weighings of resting larvæ were made from January to July and it was found that the weight constantly fell from February to July. He concludes that "the fall in weight does not necessarily demand the explanation that the larvæ were fasting, but taken along with the known fact that many hibernating or æstivating larvæ do not feed, it lends considerable weight to the probability of the larvæ not feeding during their resting period."

A very small proportion of the larvæ have not completed their growth when the cotton is picked, and these continue feeding for a while before making their resting cocoon. In some bolls examined November 26, 1918, there was an average of 6.64 fourth-instars and 0.03 third-instars per boll. After the resting cocoon is once spun no feeding takes place. If larvæ are removed from the seeds in which they are resting, other seed will sometimes be hollowed out, but the contents are thrown to the outside and no actual feeding takes place. It sometimes happens that frost does not come in the Laguna till January or February, and it is probable that feeding continues longer than usual in such years.

Duration of the Resting Stage.

Larvæ are capable of passing long periods of time in this quiescent stage. Gough (*5*) found in seeds of Indian cotton which had been imported to Egypt larvæ which were over 2 years old. Busck (*8*) in Hawaii compressed cotton seed into small bales and found live larvæ in them for 18 months. Willcocks (*7*) stored a large number of bolls picked in November, 1913, in an outdoor cage, and moths continued emerging till August 28, 1915, a period of nearly 2 years. There were 4.4 per cent of the larvæ in double seed collected in November, 1918, still alive on November 20, 1919, when work at the station was discontinued.

Pupation of Resting Larvæ.

When the resting stage has been passed in the lint, single seed, or in any place where the larva is curled up in a small, compact cocoon, it is necessary to leave this cocoon and prepare more ample quarters for pupation. In such cases a lighter, more elongate cocoon is usually spun among the fiber or seed, but in some instances in stored seed pupæ are formed without any protection whatever.

When the resting stage has been passed in the double seed the construction of the cocoon between the two seeds makes it elongate enough for the larva to pupate successfully and pupation usually takes place *in situ*. In such cases the emergence hole for the moth is cut just prior to pupation and not when the seeds are first webbed together. Often the end of the pupal shell is seen protruding from the seeds through this opening.

When pupation occurs in old bolls of cotton a favorite method is to make a slight depression in the lint and pupate between the cotton and boll. Where hibernation has been in the fields larvæ may leave the bolls and pupate in the ground. On March 14, 1919, 1½ square yards of soil in the corral at Lerdo, where many bolls were lying around, were examined. Four live larvæ and one dead one, together with one live pupa and several empty pupal cases, were found. All were near the surface, one larva being under a piece of trash and the others an inch or so down. All the larvæ and the live pupa had light cocoons and seemed to have gone into the soil for pupation rather than hibernation. In the case of the old pupal skins it could not be determined whether they came from hibernating larvæ or were left over from the previous summer.

The duration of the pupal stage from 250 resting larvæ ranged from 8 to 26 days, with an average of 10.3 days. This is an average of 1 day more than for the summer larvæ, due to the fact that pupation took place during the colder months. There is considerable individual variation in the length of pupæ formed at the same time, but this occurs in pupæ from summer larvæ as well as from resting larvæ. The pupæ from which male moths emerged required an average of one-half day more than those from which females emerged, the males requiring 10.5 days and the females 10 days.

Time of Emergence from Resting Larvæ.

A few moths may emerge throughout the year in the Laguna. When work was first begun in the early part of February, 1918, freshly formed pupæ were found among seed at the seed warehouses. During the month of March, 1918, there emerged 23.5 per cent of all the moths which emerged during the year from larvæ collected in seed in February and removed to the laboratory. Emergence continued till August, when all of the larvæ had died or emerged, the maximum being reached in May. Pupæ were formed from larvæ collected in the summer and fall of 1918 throughout the fall and into January, 1919, thus completing the cycle of pupation for every month in the year. The pupal period is greatly retarded during the cold months, but this does not prevent emergence on warm days. Table VII shows the monthly emergence of moths from resting larvæ for 1918 and 1919.

TABLE VII.—*The monthly emergence of moths from resting larvæ for 1918 and 1919.*

Months.	1918		1919	
	Number of moths emerged.	Per cent of total emergence.	Number of moths emerged.	Per cent of total emergence during period covered.
March	381	23.5	1	(1)
April	236	14.6	125	2.1
May	525	32.5	851	14.3
June	355	21.9	1,811	30.6
July	105	6.5	2,302	38.8
August	16	1.0	708	12.0
September			84	1.4
October			40	.7
November			8	.1
Total	1,618	100.0	5,930	100.0

[1] No complete record.

Moths emerging in 1918 were from larvæ collected in seed in February, 1918; those emerging in 1919 were from larvæ collected in bolls during November, 1918. Complete records are not available for December, 1918, or January, February, and March, 1919, due to absence from the laboratory. The percentages of moths emerging each month are based on the total number of moths which emerged and not upon the total number of larvæ. Of the larvæ collected in November, 1918, 4.4 per cent were still alive and had not pupated on November 20, 1919, when the records were discontinued.

A study of Table VII shows that emergence took place much earlier in 1918 than in 1919. During March, 1918, 23.5 per cent of the moths emerged and the maximum of 32.5 per cent was reached in May, while in 1919 only 2.1 per cent emerged in April and the maximum of 38.8 per cent was not reached till July. This seasonal variation depends largely upon the temperature and humidity. The winter of 1917–18 was unusually mild and there was an exceptionally hot period during the first week of March which hastened pupation. It was also found that dampening the seed or lint hastened emergence and a rain followed by warm weather in March or April would no doubt cause large numbers to emerge. As a rule, moths emerging before the first of May would find no suitable places for oviposition and would not be a factor in starting the infestation in the following crop.

ISSUANCE OF MOTH.

The issuance of the moth from the pupal skin requires a very short time. The pupal skin breaks or splits along the dorsal side and the moth works its way out and crawls upon some object in the open so that the wings may develop normally. As soon as the wings have extended to their full length they are raised and held in a vertical position from 5 to 15 minutes to become perfectly dried. Afterward the moth crawls off and hides until dark, if issuance has taken place during the day. What course is followed when issuance takes place at night was never observed.

Time of Day Moths Emerge.

The moths emerge from the pupæ at all hours of the day and night under laboratory conditions, where the temperature and humidity are more or less uniform. From Table VIII it can be seen that between the morning examinations and the afternoon examinations, 421 moths emerged in 134.5 hours, an average of 3.1 moths per hour, and that 348 moths emerged between the afternoon examinations and the morning examinations in 301 hours with an average of 1.1 moths per hour. About three times as many moths emerged during the day as emerged per hour during the night.

Table VIII.—*Time of day of emergence of the adult P. gossypiella.*

Date.	Morning examination.		Afternoon examination.		Date.	Morning examination.		Afternoon examination.	
	Time.	Number of adults.	Time.	Number of adults.		Time.	Number of adults.	Time.	Number of adults.
1919.					1919.				
May 22	10.00	(1)	5.25	27	June 4	10.00	(1)	5.30	9
May 23	9.30	16	5.30	5	June 5	10.00	22	6.00	19
May 24	9.30	2	5.30	17	June 6	10.00	25	6.00	20
May 25	10.30	15	5.30	25	June 7	10.00	14	(2)	(2)
May 26	9.30	10	5.00	27	June 8	10.00	(1)	(2)	(2)
May 27	9.30	15	5.30	26	June 9	10.00	(1)	6.00	28
May 28	9.30	17	6.00	13	June 10	10.00	20	5.00	39
May 29	9.30	13	8.30	19	June 11	10.00	26	5.00	27
May 30	9.30	11	6.30	25	June 12	10.00	41	5.30	22
May 31	10.00	46	8.30	16	June 13	9.30	8	(2)	(2)
June 1	10.00	20	6.00	15					
June 2	9.30	14	5.30	42	Total	....	348	....	421
June 3	10.00	13	(2)	(2)					

[1] All removed. [2] No record.

SEASONAL HISTORY.

The data show that moths may emerge at any time during the winter or early spring, and so far as known they may begin breeding if suitable food plants are found. Cotton does not grow as a perennial in this section. Sometimes it is left for the second year to produce a "zoca" crop, but the plants are dormant during the winter and the crop is produced from sprouts sent out from the roots or old stalks. Planting may begin during the first part of February, but usually begins about the middle, depending upon the season. Squares are not formed in any numbers until about the first of May, usually a little earlier on the zoca than on the plant cotton. Hollyhock, another host plant of pink bollworms, may be in bloom earlier than cotton, but it is considered of no economic importance in this connection. Repeated attempts to secure oviposition on young cotton plants during March and April, 1918, were unsuccessful. The first eggs were laid in the breeding jars on May 5, and the first larva (one of the third instar) was found in cotton in the field on May 15, 1918. The first eggs were deposited on April 9, 1919, and the first larva found in the field on April 28. The general infestation in the fields, however, did not begin till later in 1919 than in 1918.

In general, it may be said that breeding commences in the spring as soon as the squares begin to mature and by the time the first blossoms appear a few larvæ are present. The infestation is extremely light at this season and only by careful search will any larvæ be found. As a rule the bolls are not attacked till they are from one-half to three-fourths grown, though occasionally a larva works down from the blossom to the newly set boll. It is usually about the middle to latter part of July before bolls on plant cotton are sufficiently mature to be attractive to the larvæ. From this date onward the infestation rapidly increases, and in about 10 weeks' time practically every green boll is infested. The cool nights of October and November check the development somewhat, but breeding continues until frost destroys the food plants.

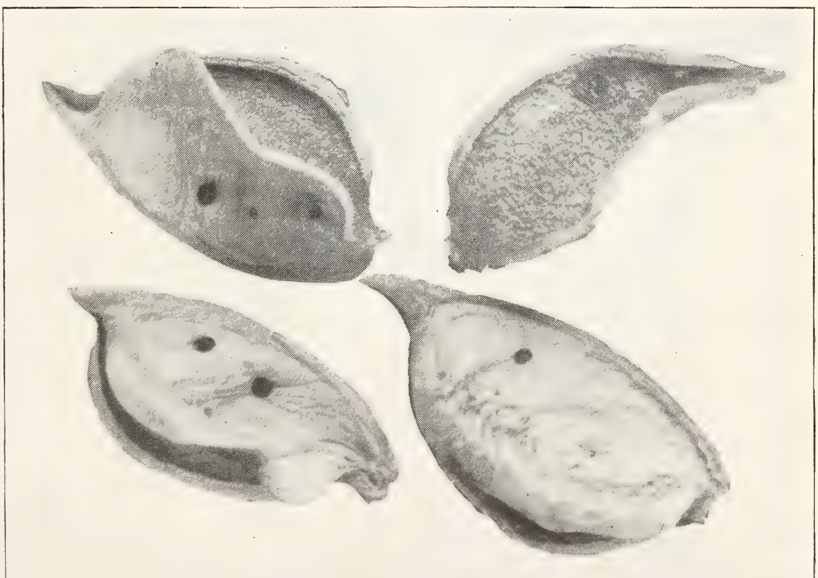
Table IX shows the weekly increase in the percentage of green bolls infested during the 10 weeks during which breeding is most active. It is computed from weekly examinations of samples of green bolls collected on different plantations, an average number of 350 in 1918 and 1,100 in 1919 being used.

TABLE IX.—*The weekly increase in the percentage of green bolls infested with Pectinophora gossypiella.*

Week ending—	Percentage of green bolls infested.		Week ending—	Percentage of green bolls infested.	
	1918.	1919.		1918.	1919.
July 12	1.1		Aug. 30	79.2	20.8
July 19	7.0		Sept. 6	93.0	29.0
July 26	13.6		Sept. 13	97.3	41.0
Aug. 2	20.0		Sept. 20		45.0
Aug. 9	21.0	4.3	Sept. 27		63.0
Aug. 16	42.0	5.0	Oct. 4		83.3
Aug. 23	65.8	10.8	Oct. 11		100.0

From Table IX it is seen that the time of active breeding varies considerably, and that in 1919 it was a month later than in 1918. This depends largely upon the development of the cotton. The same climatic conditions which retard the growth of the cotton also affect the activity of the species, and the relative development of the two is about the same from year to year. It is also clearly shown that there are no distinct broods or generations and that the heavy infestation in the fall is accumulative. If the offspring from moths emerging early in the spring continue breeding throughout the

A, Characteristic rosette appearance of cotton flowers infested with the pink bollworm.



B, Holes cut through partition wall when larva goes from one lock to another. (Hunter.)

PINK BOLLWORM.

season till December and make a complete life cycle every 31 days, there are six generations, but if the moths do not emerge from the resting larvæ until the fall and the first generation goes into the resting stage again, the whole year may be passed in only one generation.

FEEDING HABITS OF LARVÆ.

LARVÆ FEEDING ON LEAVES AND STEMS.

The feeding of the pink bollworm on the leaves of cotton is of no economic importance. It is a forced condition rather than a voluntary one. If the eggs have been deposited a long way from the squares or bolls, the larvæ may feed slightly on the leaves while searching for suitable food. In such cases slight abrasions on the surface of the leaf or minute pinholes through the leaf occur. The larvæ feeding in this manner appear either to die for lack of sufficient nourishment or to be destroyed by other insects. No larvæ older than those of the second instar were ever observed feeding on leaves and only two or three cases of the second instar. No indications of entrance into the bolls by larvæ of the second or later stages were ever observed under field conditions, except where the larvæ had been feeding in blossoms and had worked downward into the newly set bolls. Willcocks (7) records larvæ feeding in the stems of the plants just above the surface of the ground in Egypt, but this class of injury was never seen in the Laguna.

LARVÆ FEEDING IN SQUARES AND FLOWERS.

The young larvæ enter the squares by cutting directly through the undeveloped flower petals and feed on the pollen and fleshy parts of the embryonic flower, usually reaching the third or fourth instar by the time the flower opens. These infested flowers do not open normally, but have a peculiar rosette appearance which is well shown in Plate III, A. The tips of the corolla in infested flowers are webbed together by the larvæ with fine silken threads which prevent their opening wide and exposing the larvæ to the attacks of other insects and the heat of the sun.

These infested flowers are easily distinguishable from normal flowers in walking through fields of upland or short-staple varieties. Even though the percentage of infested flowers was about the same in Egyptian or long-staple cotton the pronounced rosette effect was never seen. The corolla is longer and larger in Egyptian varieties and the threads spun by the larva probably are not sufficiently strong to prevent its opening. When infested flowers are examined the larva is usually found beneath a fine silky web, covered with frass and pollen grains, and feeding upon the anthers. If full-fed when the flower opens it may leave it the first day and drop to the ground for pupation. This is especially apt to occur if the larva is disturbed by other insects, such as the flower beetle, *Euphoria basalis* Gorg. If the larva is not full-fed at the time of opening it may continue feeding inside the flower for two or three days or until after the flower has dropped, or it may work downward from the flower into the newly formed boll. No indication of the larva leaving flowers and going into large bolls was ever observed, and it is exceptionally rare to find more than one larva in a single square or flower. From June 1 till August 10, 1919, a daily record, with a few exceptions, was kept of the flowers opening on a small plot of heavily infested cotton at Ciudad Lerdo. The results are given in Table X.

TABLE X.—*Infestation of cotton blossoms by the pink bollworm.*

Month.	Number of days counted.	Infested.	Non-infested.	Total.	Percentage infested.
June	25	226	8,210	8,436	2.7
July	25	898	12,333	13,231	6.8
August	10	967	2,508	3,475	27.8

On October 3, 50 per cent and on November 10, 90 per cent of the flowers on this same plot were infested. This plot was more heavily infested than is normally the case under field conditions. The infestation is usually highest in June and July, when few large bolls are present on the plants, and decreases during August and September. In October and November, when there are many larvæ present and not so many green bolls, the infestation again increases and the few blossoms appearing at this time are heavily infested. As the feeding in the squares and blossoms is largely on the pollen, the presence of a larva does not necessarily prevent a normal boll from forming. Blossoms were tagged in 1919 and it was found that 40.8 per cent of the noninfested squares and 67.6 per cent of the infested blossoms were shed.

LARVÆ FEEDING IN BOLLS.

That inside the bolls is the most favored feeding place for pink bollworms is shown by the fact that as soon as the bolls are large enough most of the larvæ choose bolls instead of squares or flowers. They attack the boll in all stages of its growth, from the time it is the size of a pea until it begins to open, though most commonly it is not entered until about one-half to three-fourths grown. The larvæ bore into the boll at any point upon its surface soon after hatching and remain in the same boll until ready for pupation. Once the larvæ have entered the boll no definite plan of procedure is followed. They may burrow directly through the carpel and begin feeding on the soft watery lint or they may stop before cutting completely through and burrow for an inch or more in the spongy carpel tissues just beneath the inner wall of the boll. In the latter case they leave brownish, discolored tunnels or burrows resembling the work of young leaf miners. These tunnels, commonly called "railroads," are very characteristic of pink bollworms and when found are sure evidence that a boll is infested. They disappear as the boll grows older and are not noticeable in an open boll.

When the larvæ cut directly through and into the lint sometimes a slightly discolored proliferation resembling a puncture made by a cotton stainer is formed and at other times only a slight discoloration is left. Again, a larva may be found inside a boll and no sign of its entrance place found even when the boll is examined from the inside. The larvæ may tunnel in the carpel tissues or feed in the lint in any direction from the point of entrance and seldom if ever feed on seed until after the first molt. They may burrow between or cut through the fibers of the lint for a considerable distance while feeding on the soft tissues, leaving behind slightly discolored trails through the lint and "railroads" through the immature seed coats; or, on the other hand, they may remain feeding on the lint near the point of entrance.

Second or third instar larvæ are found which seem to have fed exclusively on the lint, but there is always some feeding on the seed before the larvæ become fully mature and second and third instars are frequently found in the seed. The seeds are normally first attacked from the broad end nearer the outer surface of the boll. The contents of the first seed attacked are not eaten completely out before an adjoining seed is attacked. The number of seeds attacked by a single larva varies greatly, due to the age and development of the boll at the time of attack and the behavior of the larva. Cases have been seen where a larva completed its development on as few as two seeds and within a short distance of the place of entrance, while another larva may destroy a whole lock or more. Often a larva will cut through the partition into the adjoining lock instead of going to another seed in the same lock. The hole in the partition is clean cut, round or oval, and is good evidence that a pink bollworm has been in that boll. Plate III, B shows these holes.

When very small bolls are attacked by larvæ working downward from the flowers, they turn brown and usually drop from the plants, but if the bolls are not attacked till about half grown, the presence of larvæ does not cause them to shed. When there are only 2 to 4 larvæ in a boll that is rather far advanced, say three-fourths to full-grown, when attacked, the work may be classed as "clean," but if several larvæ have attacked a boll that has not reached that stage, the entire contents are very likely to be completely broken down into a decayed mass. The presence of larvæ in bolls does not prevent other larvæ from entering, and usually larvæ of all stages are found in the same boll. During the latter part of the season, when the infestation is heavy, an average of 6 or 7 larvæ is found per boll and individual bolls may contain many more. One boll was examined that contained 26 larvæ. The number for all bolls examined throughout the season of 1919 averaged 2.5.

PROLIFERATION OF BOLLS.

The presence of larvæ often causes the bolls to form abnormal growth or proliferation. Proliferation is described by Dr. W. E. Hinds (*1*) as:

> The development of numerous elementary cells from parts of the bud or boll which are themselves normally the ultimate product of combinations of much more highly specialized cells. The resulting product is thus composed of comparatively large, thin-walled cells, which are placed so loosely together that the resulting formation is of a soft texture, and has a granular appearance which may be plainly seen with the unaided eye.

Greenish white or discolored brownish opaque swellings are formed on the inner wall of the carpel, the seeds themselves proliferate, and very little if any lint is formed on them. This spongy mass of granular cells develops much more rapidly than lint, thus occupying the space that would have been filled with lint. Badly proliferated bolls contain but little lint, and this is matted or felted and of poor quality, thus greatly increasing the damage done by the pink bollworms. Proliferous seeds are not confined to those actually attacked by the larvæ. The irritation caused by the presence of the larvæ in a boll or the stimulation from proliferation in seed actually injured causes other healthy seed to proliferate. The percentage of proliferous bolls increases very rapidly with the advance of the season, which is simultaneous with the increase of the number of bolls attacked by the pink bollworm and with the number of larvæ in each boll. The Egyptian cotton grown at the laboratory was much more severely affected by proliferation than were the short-staple varieties. Larvæ occasionally are killed by proliferation, but from general observations it is thought that not more than one-tenth of 1 per cent are killed in this way. The result is by far more detrimental than beneficial.

DAMAGE CAUSED BY THE PINK BOLLWORM.

The damage by the pink bollworm is caused by the feeding of the larvæ on the squares and blooms, the walls and partitions of the bolls, and the lint and seed of the cotton. Upon entering the boll after hatching the larvæ feed on the lint and tender tissues of the boll during its earlier stages of growth; in the latter stages the larvæ feed almost exclusively on the seed, thereby arresting the development of the lint and seed and also destroying the seed itself. In passing from seed to seed and from lock to lock the larvæ cut and discolor the lint. Just as soon as the bolls are formed they may be attacked by the larvæ working downward from the flower, but usually they are not attacked till one-half to three-fourths grown. The damage to the individual boll is greater the earlier it is attacked. In case the larva enters when the boll is very young, that is, one-half grown or less, the boll is usually completely destroyed. But when a boll is not attacked until it is about half grown an infestation by a larva or even several larvæ does not necessarily prevent the boll from opening and producing some pickable cotton. The cotton from infested bolls is of an inferior grade, the lint usually being short, hard, and kinky. The portion of the boll actually consumed by the larva may be comparatively small, but the damage caused by the feeding habits and presence of larvæ in a boll amounts to a considerable percentage loss to the crop. The irritation produced by the presence of a larva often causes proliferation to take place; and upon entering and leaving the boll the larvæ provide a means for the entrance of air and water, thereby causing decomposition in the green bolls.

RELATION OF AMOUNT OF DAMAGE TO INCREASE OF INFESTATION.

It has been estimated that the natural winter mortality of all insects is about 95 per cent or more. In addition to this, the number of pink bollworms in the cotton fields of the Laguna district is further reduced by the irrigation methods, fall burning of plants, and the grazing of the fields by cattle, goats, etc. It is obvious that at the beginning of the crop the infestation, even where it was general the previous year, would be very light, but as the number of larvæ in the field increases the amount of damage becomes greater.

The pink bollworm attack is not similar to that of other insects like the cotton leafworm, *Alabama argillacea* Hübn., or bollworm, *Chloridea obsoleta* Fab., which practically ruin a crop overnight, but is more of a gradual, built-up attack, starting in the beginning of the crop with practically a negligible infestation and culminating with 100 per cent of the bolls infested with from 4 to 10 larvæ in every boll. Table XI shows the rate of monthly increase of larvæ in several average fields of the Laguna.

TABLE XI.—*Progress of infestation by larvæ of the pink bollworm; number of larvæ per 100 bolls.*

Month.	Plantation.							Average.
	Hormiguero.	Alvia.	LaConcha.	San Isidera.	Zaragosa.	Rosas.	Barcelona.	
August	2.6	15.3	5.0	5.2	32.6	33.6	17.6	15.9
September	103.0	128.7	93.5	62.7	312.0	210.7	188.0	156.0
October	710.0	694.0	585.2	748.0	773.0	807.4	496.6	662.9
November	920.0	790.0	668.0	638.0	....	864.0	464.0	724.0

The data in the foregoing table were compiled from records kept of weekly examinations made of 100 boll (green) samples taken from different plantations in the Laguna district. The bolls in each sample were taken by walking through the same fields each week and picking the bolls at random.

ESTIMATE OF DAMAGE TO LAGUNA CROP, 1919.

In making an estimate of the damage caused by *P. gossypiella* to the cotton crop of the Laguna for 1919, it was thought best to select certain average fields on average plantations and to keep these particular fields under close surveillance during the entire year.

Through the courtesy of Don Carlos Gonzales y Fariño, of Torreon and of the Tlahualilo Company, Tlahualilo, Durango, certain fields upon their properties were selected. These fields were chosen with the utmost care in order to obtain as nearly as possible an average of all conditions of the Laguna, with respect to factors controlling the amount of damage caused by *P. gossypiella*. Other fields in different parts of the Laguna were examined as often as time would permit for comparison with these fields. Each of these fields was visited regularly (as far as conditions would permit) once a week, and samples of 100 green bolls taken, so that the rate of increase of infestation might be ascertained.

Samples of seed cotton were also taken at the beginning of each pick from each of the experimental fields, to determine the damage caused by the pink bollworm in the different harvesting periods. These samples were ginned in a sample gin separately, accurate weights being kept of the quantity of lint and seed. A sample of lint from each field sample was taken for classification by the Bureau of Markets, United States Department of Agriculture, to determine the discolorations, grades, and spinning qualities of the lint.

A 2-pound sample of seed was taken from each field sample for chemical analysis to determine quality and quantity of oil.

DAMAGE TO SQUARES AND BLOOMS.

The pink bollworms enter the squares just after hatching from the eggs, and continue feeding until they complete the larval stage, notwithstanding the fact that the squares may bloom in the meantime. Larvæ of all stages have been found in the squares, but generally speaking only full-grown larvæ have been observed in the blooms. To ascertain to what extent this floral feeding habit tended to cause damage the following experiment was carried on.

Tags were placed on 343 normal blooms and on 343 infested blooms during June and July. Table XII shows the results.

TABLE XII.—*Results of experiment to determine damage caused by feeding of the pink bollworm in the blooms of cotton.*

Blooms.	Number of tags.	Dropped off.	Set bolls.	Per cent of blooms dropped.
Normal	343	140	203	40.8
Infested	343	232	111	67.6

From the above table it will be seen that 40.8 per cent of the *normal blooms* did not set bolls, but 67.6 per cent of the *infested blooms* did not set bolls, a difference of 26.8 per cent. Granting that under favorable conditions the natural tendency of the plant will be to reset these fruits, it is obvious that 26.8 per cent 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 later maturity of the crop due to shedding of the early squares would also greatly increase the damage by the boll weevil in countries where this insect is present. (See Table XI on "Progress of infestation.")

The rate of monthly increase of the infested blooms in a given field is shown in Table X.

DAMAGE TO BOLLS.

In estimating the damage caused to the mature bolls (Pl. I), pickable as well as nonpickable cotton must be considered. By pickable cotton is meant cotton that is picked, ginned, and marketed from the beginning to the end of the crop; by nonpickable cotton, the bolls or portions of bolls that are left on the plants as unfit for picking, due to damage by the pink bollworm.

PICKABLE COTTON.

To arrive at a conclusion as to the extent the cotton taken from the fields is damaged, a 100-pound sample of seed cotton was taken from each picking in each experimental field. These samples were taken by picking all the open cotton on about every twentieth plant in each row, in this manner obtaining as nearly as possible a composite average sample of the cotton open in the field on that date. After the sample was taken the remaining open cotton was picked in the customary manner, thereby guarding against the possibility of mixing any of the first and second pick cotton in the taking of the later samples.

The samples were stored until the end of the season and then ginned separately, using a small 10-saw sample gin. A gin sample of approximately 2 pounds of lint and a sample of seed weighing about 2 pounds were taken from each of the field samples at the time of ginning.

Loss in the Quality of Lint.

The 2-pound gin samples were sent to the United States Bureau of Markets for examination. Mr. George Livingston, Chief of Bureau, reported in letter dated April 13, 1920, as follows:

In a general way it may be stated that all of the samples were of very poor quality, especially as regards length and strength of staple. The results obtained through the ordinary commercial classification of cotton were confirmed by individual fiber strength tests which produced subnormal results. It is commonly considered that upland cotton should show an average strength for individual fibers of about 8 grams, but none of the Mexican samples possessed that degree of strength. Several of the samples were so weak that a considerable portion of the fibers broke upon being inserted in the jaws of the testing machine. Such cotton is so weak in staple as to be practically unspinnable.

The exact degree of the deterioration in the quality of lint mentioned above which is due to the pink bollworm can not be definitely stated, but undoubtedly a certain percentage of it is caused by malnutrition of the seed, which arrests the development of the lint. Ballou (*11, p. 265*) states:

In addition to the actual damage done to the lint and seed of the attacked seed, there is the injury which results to sound seed in attacked bolls. This appears to be a matter of malnutrition, the attacked seed making demands on the supply of the plant food to such an extent that nearly all the seeds in the boll are deprived of a portion of their nutriment.

Loss in Weight of Seed.

As the amount of seed destroyed or practically destroyed by *P. gossypiella* was found to assume proportions worthy of considerable notice, an attempt was made to ascertain the exact loss by weight caused in this manner. From material picked during the year, samples of seed cotton were accurately weighed, hand-ginned, and the seed examined individually and weighed, with the following results:

Table XIII.—*Loss by weight to seed when hand ginned.*

Sample.	Weight of sample.	Total number seed.	Sound seed.			Damaged seed.				Lint.	
			Number of seed.	Weight in grams.	Average weight per seed in gram.	Number of seed.	Weight in grams.	Average weight per seed in gram.	Loss in weight per seed in gram.	Weight in grams.	Per cent.
First pick, Zaragosa.	458 gms. (1 lb.)	2,438	2,282	252.65	0.1107	156	8.80	0.0561	0.0546	158.12	34.5
Second pick, Zaragosa.	...do....	2,855	2,388	244.38	.1023	467	34.40	.0736	.0287	159.5	34.8
Third pick, San Isidera.	...do....	3,678	1,753	180.20	.1027	1,925	125.30	.0651	.0376	141.5	31

Table XIII shows there was a smaller number of seeds in the sample from the first pick but that the individual seeds were heavier and the percentage of lint in the two samples was practically the same.

The damaged seed from the first pick weighed less per seed than from the second pick, and the damage per seed from the first pick was greater than in the second pick. This is probably because the bolls from the first pick were attacked when they were greener and the seeds were attacked when they were more immature than in the other picks. There is no indication that the number of seeds per boll is reduced on account of pink bollworm attack, as pointed out by Gough. Unfortunately, the sample of the third pick is from a different plantation and is not quite comparable with the other samples. It may be pointed out, however, that the average weight of the sound seed in the second and third picks is almost the same and that the loss in the individual attacked seed is greater in the third than in the second pick. This is thought to be because a much larger number of larvæ had prepared to hibernate in the third pick and a hibernating larva needs all the available space, especially in the single seed, and had eaten out the kernels of the seed cleaner to prepare this space. From the data given in Table XIII the loss in weight of the seed in the different picks can be calculated, and this is summarized in Table XIV.

Table XIV.—*Summary of table showing the loss in weight of the seed from the different picks due to pink bollworm attack.*

Pick.	Actual weight of seed (grams).	Loss in weight of infested seed (grams).	Corrected weight of seed (grams).	Per cent of loss in infested seed.	Per cent of total seed lost.	Remarks.
First	261.45	8.42	269.88	3.1	1.24	First pick=40 per cent crop.
Second	278.78	13.40	292.18	4.6	1.84	Second pick=40 per cent crop.
Third	305.50	72.38	377.88	19.1	3.82	Third pick=20 per cent crop.
Total					6.90	

Table XIV shows a loss of 3.1 per cent in the weight of the seed from the first pick, 4.6 per cent of the second pick, and 19.1 per cent in the third pick. The data secured in 1919 showed that 40 per cent of the crop was harvested in the first pick, 40 per cent in the second, and 20 per cent in the third. The losses in the seed from the different picks when given their proportionate weights with respect to the proportion of the total crop harvested in each pick show that 1.24 per cent of the total seed was lost in the first pick, 1.84 per cent in the second pick, 3.82 per cent in the third pick, or that a total of 6.90 per cent by weight of the seed is lost due to the attacks of the pink bollworm in the pickable cotton.

When the above-mentioned field samples of seed cotton were ginned the seed of the first, second, and third picks were placed in separate piles. Using a 20-liter measure, an equal number of weighings were made of the seed from each pick to determine the loss in weight between the seed of the different picks (Table XV).

TABLE XV.—*Weight of even number of containers of cotton seed for each pick.*

Sample No.	First pick.	Second pick.	Third pick.	Sample No.	First pick.	Second pick.	Third pick.
	Kilos.	*Kilos.*	*Kilos.*		*Kilos.*	*Kilos.*	*Kilos.*
1	10.5	10.5	10.5	8	11.1	10.7	10.7
2	11.0	10.7	10.6	9	10.9	10.9	10.5
3	11.1	10.6	10.6	10	11.0	10.5	10.6
4	11.3	11.0	10.5				
5	11.1	10.9	10.6	Total	110.4	107.5	106.2
6	11.2	10.8	10.8	Average	11.04	10.75	10.62
7	11.2	10.9	10.8	Net weight	6.24	5.95	5.82

Weight of container, 4.8 kilos: container used=20 liters.

From Table XIV it is shown that there is 3.1 per cent loss in weight in the seed from the first pick; therefore the weight of one 20-liter measure (6.24 kilos) would be equal to only 96.9 per cent of the weight of sound seed, and the corrected weight of a 20-liter measure of sound seed should be 6.43 kilos.

From these data it is shown that there is a loss of 0.19 kilo in the seed of the first pick, 0.48 kilo in the second pick, and 0.61 kilo in the third pick. These losses reduced to a percentage basis would equal 2.9 per cent of the seed lost in the first pick, 7.4 per cent in the second pick, and 9.4 per cent of the third. But as 40 per cent of the crop was harvested in the first pick, 40 per cent in the second pick, and 20 per cent in the third pick, these figures when given their weighted values will equal 5.96 per cent of the total seed lost due to pink-bollworm attack.

This difference of 0.94 per cent between the figures representing the total loss in the seed when hand-ginned and when commercially ginned is explained by the fact that part of the damaged seed is broken in cleaning and ginning the cotton, and passes out with the cleanings, trash, and even in the lint. It is thought, therefore, that the figure given for the hand-ginned sample, 6.9 per cent, represents more nearly the actual loss in the seed of the pickable cotton than does the figure 5.96 per cent obtained from the commercially ginned sample.

LOSS IN QUANTITY AND QUALITY OF OIL.

Besides the losses in the weight of the seed, there is also an additional loss in quantity and quality of the oil produced.

Because of the danger of introducing the pink bollworm into the United States, it was thought advisable not to bring seed out of Mexico for analysis. Samples were taken from the different field samples as ginned and given to the chemists of the largest oil mill in the Laguna district. Owing to the unsettled conditions prevailing in that section of Mexico during 1920, reports on these samples have not been received.

Willcox (7) states that there is marked reduction in the quantity of oil produced and that the quality is of an inferior grade.

NONPICKABLE COTTON.

It is in this class that the major portion of the gross damage occurs. As has been previously stated, there is a certain percentage of the cotton damaged to such an extent as to render it unfit for picking. This cotton naturally is left on the plants after the pickings are finished.

An effort has been made to determine the exact portion of the crop that is affected in this manner. By selecting what appeared to be average-sized plants (according to the number of bolls per plant, etc.) in fields of several different average plantations, about 3,000 plants were examined after the cotton had been picked. These plants were examined individually, the total number of bolls on each plant and total number of bolls lost on each plant due to attack of the pink bollworm being recorded. In counting the total number of bolls an empty burr was counted as a boll, and in the calculations has the weight of a perfectly sound boll.

In counting "bolls lost," only bolls or portions of bolls which showed plainly that their damage was caused by the pink bollworm were taken into consideration. Bolls or portions of bolls that showed themselves to be unfit for picking because of conditions other than the pink bollworm, such as those attacked by the common bollworm, *C. obsoleta*, or injured by water, heat, and dryness, were counted as sound bolls (Table XVI).

TABLE XVI.—*Loss to crop in nonpickable cotton caused by the pink bollworm.*

Place.	Total plants.	Total bolls.	Total bolls lost.	Per cent damaged
Hormiguero	248	6,737	1,066	15.82
Alvia	453	14,977	2,618	17.48
La Concha	503	15,117	2,942	19.46
San Isidera	454	20,112	3,768	18.73
Zaragosa	450	10,428	2,544	24.39
Rosas	450	9,282	2,318	24.97
Barcelona	300	6,297	1,325	21.04
Total	2,858	82,950	16,581	141.89
Average				19.98

Table XVI shows that of 82,950 bolls produced by 2,858 plants 16,581 were lost, making a total of 19.98 per cent damage in the nonpickable cotton due directly to the attack of the pink bollworm. The plantations on which these figures are based represent a true average of the entire Laguna. In addition to these plantations, a number of other places were visited in different parts of the Laguna and the amount of damage found ranged from 15 to 25 per cent, with an average of approximately 20 per cent loss due to the pink bollworm, which substantiates the accuracy of the foregoing estimates.

SUMMARY OF DAMAGE BY THE PINK BOLLWORM.[4]

(1) Loss in squares and blooms: 26.8 per cent of the squares and blooms shed.

(2) Loss in pickable cotton:
  Lint: Deterioration in quality.
  Seed: Is reduced 6.9 per cent in weight; quantity and quality of oil also reduced.

(3) Loss in nonpickable cotton: 19.98 per cent of entire crop rendered unpickable.

The damage to the nonpickable cotton and the loss by weight in the seed in the pickable cotton can be reduced to a monetary basis. Assuming lint to be worth 30 cents per pound and seed worth $60 per ton, the value of 500 pounds of lint would be $150 and 1,000 pounds or ½ ton of seed would be worth $30, or a total of $180 per bale. For every bale picked there is 19.98 per cent of the seed and lint left in the field as nonpickable cotton, or, in other words, the amount of cotton actually picked represents only 80.02 per cent of the crop if no pink bollworms were present. Then the value of the crop produced would be $224.90 rather than $180. The loss of 19.98 per cent of the potential crop ($224.90) is equal to $44.93 per bale. In addition to this there is 6.9 per cent loss by weight in the seed of the pickable cotton (which represents the 80.02 per cent of the bale not included in the 19.98 per cent loss or nonpickable cotton), which amounts to $2.07. Therefore the total loss is $47 or 20.89 per cent of the value of the bale.

The calculable loss that can be specifically stated on a definite percentage basis is 20.89 per cent. In addition to this figure there should be added the losses incurred in the shedding of the squares, deterioration in the quantity and quality of the oil in the seed, and the weakening and irregularity of the staple in computing the total damage caused by the pink bollworm.

FOOD PLANTS.

While cotton (*Gossypium* spp.) is by far the most favored food plant, a number of other plants have been recorded as host plants of the pink bollworm. Maxwell-Lefroy (*2*) records a species of Hibiscus and the oily seed of trees (species not given) in India; Fullaway (*3*) reared a single specimen from milo (*Thespesia populnea*) in Hawaii;

[4] *Damage during 1920.*—The damage to the Laguna crop by the pink bollworm was unusually severe during 1920. Frost did not come in 1919 till very late and this was followed by a mild winter, which allowed a large percentage of the hibernating larvæ to pass the winter successfully. The fields were examined during the latter part of June, and it was very evident that the infestation in squares and young bolls was heavier than it had been in 1918 or 1919. The cotton was also further advanced and was growing rapidly, with very good prospects for a large crop. About this time there were severe outbreaks of aphids (*Aphis gossypii*), thrips, and rust (*Aecidium gossypii*) which checked the growth of the plants and gave them a setback from which they never recovered. This caused the plants to produce very few bolls, and the infestation by the pink bollworms and the percentage of loss have consequently been very high. Estimates made in November showed that the pink bollworm had injured 31.3 per cent of the crop so badly that it was rendered unfit for picking and that there was 7 or 8 per cent additional loss attributable to the insect by the lowering of the quantity and quality of the pickable cotton, or a total of 38 to 39 per cent loss of the crop.

PINK BOLLWORM.

Larvæ feeding in the walls of the pods and seed of okra.

Busck (*8*) bred the pink bollworm from *Gossypium tomentosum* in Hawaii, but did not find it in milo; King (*9*) reports it from hanbuk (*Abutilon* sp.) in Africa; and Gough (*12*) records mallow (*Malva* sp.). Willcocks (*7*) states that the food plants in Egypt are bamia or okra (*Hibiscus esculentus*), teel or hemp (*Hibiscus cannabinus*), and hollyhock (*Althaea rosea*).

A number of malvaceous plants were grown beside heavily infested cotton on the laboratory grounds and several became infested. Okra (*Hibiscus esculentus*) became rather heavily infested in every instance when grown in close proximity to cotton. Table XVII is a complete record of all the seed pods grown on 30 plants at the laboratory during the season of 1919. From August 14 to December 3, 590 seed pods were examined with the following results: 66.7 per cent were infested with live larvæ and pupæ, and the total infestation, including seed pods that were unmistakably infested but in which no larvæ or pupæ were found, was 73.8 per cent. The infested seed pods averaged 2 larvæ, pupæ, and exit holes.

TABLE XVII.—*Seed-pod examination of Okra* (*H. esculentus*).

Number of pods.	Pods infested.		Infestation.			Number of infested pods without larvæ or pupæ present.	Number of exit holes.	Remarks.
	Number.	Per cent.	Larvæ total.	Number of pupæ.	Pupæ and larvæ.			
38	11	28.9	9	0	9	3	0	Green pods.
33	9	27.2	9	0	9	1	0	Do.
60	36	60.0	48	0	48	1	0	Do.
50	35	70.0	85	0	85	3	0	Do.
100	69	69.0	105	0	105	13	25	Do.
100	79	79.0	106	5	111	13	37	Do.
50	45	90.0	92	4	96	2	13	Dry pods.
84	66	78.5	147	5	152	5	8	Do.
20	12	60.0	37	0	37	1	0	Do.
20	17	85.0	35	0	35	1	1	Do.
35	15	42.8	21	0	21	0	0	Green pods.
590	394	66.7	694	14	708	43	84	

From this one observation it seems that when attacking okra the pink bollworm is more inclined to pupate in the seed pods than in the bolls when cotton is attacked. No plausible explanation can be given as to why this should occur.

The manner of attack and feeding habits in okra are essentially the same as in cotton, but no larvæ were ever found feeding in the flower buds or flowers.

Double seeds or three or four seeds are frequently webbed together in much the same manner as double seed in cotton, though the work is not so clean and particles of frass are usually found attached to them. Plate IV shows full-grown larvæ feeding in okra pods.

One important point to be determined is whether the species is able to sustain and perpetuate itself on okra alone as a food plant. Two large screen cages were constructed over heavily infested okra in the fall of 1918. The entire plants with the fruits attached were left in the cages during the summer of 1919. Repeated examainations were made of all fruits formed during 1919 and no infestation ever developed from the hibernating larvæ. The protection afforded by the okra is not as good as the protection afforded by cotton. The seed pods crack open on drying and the seeds with the larvæ webbed up in them drop to the ground, the larvæ becoming subject to the detrimental effects of water and attacks of insect enemies.

Under the same conditions hollyhock (*Althaea rosea*), a very common ornamental flower, was found to be subject to the attack of the pink bollworm larvæ, the insects being found in the buds, flowers, and seed pods.

Hibernating cages were also constructed over hollyhock plants and experiments conducted in the same manner as with okra with negative results. No reinfestation occurred from hibernating larvæ.

The flower buds, flowers, and seed pods of *Hibiscus syriacus* were attacked by the pink bollworm, the manner of attack and feeding habits being the same as in cotton and okra. The infestation in the flower buds was light, but the seed pods were nearly all infested and some contained several larvæ.

One pink bollworm larva was taken from a seed pod of the Confederate rose (*Hibiscus mutabilis*).

Seeds from 25 species of malvaceous plants were collected in southern Texas and planted in close proximity to cotton at Ciudad Lerdo. Of this number only the following species grew: *Hibiscus coccineus* Walt., *Hibiscus militaris* Cav., *Hibiscus lasiocarpus* Cav., *Malvastrum americanum* (L.) Terr., *Sida spinosa* L., *Wissadula lozani* (Rose) Fries, and *Kosteletzkya virginica* L. Some of these have small seed pods and are not well adapted to the feeding habits of the larvæ, but the following species were attacked by pink bollworms.

Only one plant of *Hibiscus coccineus* grew. It developed 7 seedpods and 5 of these were infested.

Hibiscus militaris was attacked both in the flowers and seed pods. The same rosette appearance takes place in the infested flower as in upland cotton.

Kosteletzkya virginica was also attacked. The plant is a very profuse bloomer, but the seed pods are rather small to be well adapted for the larvæ, though two full-grown larvæ were found in seed pods.

Malvastrum americanum was infested. One specimen was taken in a seed pod.

A species of Malva (*Malva parviflora* L. ?) grows rather abundantly along the borders of the fields in the Laguna, but was never found to be infested under natural conditions. The seed pods are too small to be well adapted for pink bollworms, though larvæ can reach maturity in a single pod.

DISPERSAL.

The most important factor in the dispersal of the species is man. By his transportation of cotton seed and cotton products he has carried the insect from its original home to all parts of the cotton-producing world. Once it is established, local dispersal from one field to another is also by flight, and in some instances the carriage of the larvæ by water is of importance.

CARRIAGE OF LARVÆ IN SEED FOR PLANTING AND OTHER PURPOSES.

The transportation of infested seed by man from place to place is the usual means by which this insect is carried to new localities. It was introduced into Mexico in 1911 with seed for planting; into Brazil in 1911–1913 with seed for planting; and more recently into certain parts of Texas with seed in cotton and seed for milling purposes. From what has already been stated concerning the habits of the pink bollworm, it is evident that seed from an infested field is sure to contain a certain percentage of infestation, and it is known that the resting larvæ can live for at least 2 years in such seed. It is thus seen that the larvæ are admirably adapted for transportation over great distances in this way. Seed, moreover, is often incidentally carried with other products. Railroad cars which have been used for shipping cotton seed are a very dangerous example of this. Seed will usually be found in the cracks and corners and between the walls of the car. Numerous instances of this have been noted, particularly by inspectors at border points, where live pink-bollworm larvæ were taken from cars which had been used for seed in the Laguna district and later used for exportation of other products. Bales of cotton often carry seed and as many as several hundred seeds have been found mixed with the lint and attached to the bagging. Cotton waste and used cotton bagging are other items usually having seed attached to them. Cotton pickers in Mexico often move from plantation to plantation. It is a common practice with them to carry their own picking sacks and among their belongings seed cotton and cotton seed are often found. These and similar practices are common means by which the insect is carried.

FLIGHT AND CARRIAGE OF ADULTS.

While the moth of the pink bollworm is small, it has ample wing power for its size and is capable of quick, darting flight. When disturbed during the day it flies only a short distance and hides under the nearest object. On the other hand, several hundred moths were liberated on top of the house where a light breeze was blowing, in the morning and at dusk. About half of those liberated in the morning flew only a few feet before settling down, while the others flew upward and away as far as the eye could follow them. Those liberated at dusk nearly all flew upward and away till lost to sight. In all cases they flew with the wind and not quartering to it, as some insects do. Up to the present time no conclusive data have been accumulated along this line, due to the nocturnal habits of the moth and the fact that in Mexico it was so generally distributed that no uninfested isolated fields were found.

The average duration of the moth stage in captivity is about 14 days. If the moth flies only a short distance before coming to a rest, it would appear certain that it may again proceed for another short distance. If there were nothing to influence the direction of its flight, it might fly in any direction and as likely as not return to its original starting point; but if the direction of the flight is influenced by the wind, as it was in our observations, it would fly with the wind, and where there is a prevailing wind from one direction the moth would be carried in the same general direction farther and farther from its starting point and might cover a considerable distance before dying. In the eradication work in Texas a 5-mile non-cotton zone around infested territory is used to prevent dispersal by flight, and it is thought this zone is reasonably safe. The moths have seclusive habits, and frequently hide in cracks, crevices, and dark corners. At the railroad stations in the Laguna cars stand upon the side tracks within a few yards of the cotton fields for days or even weeks at a time while being loaded and unloaded. Trains stop for long periods of time near the fields to unload supplies, and when these stops are made at night, when the moths are flying about, it is possible that some of the moths might secrete themselves in the cars and later be carried to distant points. There is the same danger, though to a lesser degree, in vehicles passing cotton fields along the roads.

CARRIAGE OF LARVÆ BY WATER.

Cotton plants with bolls attached were often seen floating down the Rio Nazas when it was at flood stage, and old bolls are carried long distances when fields are overflowed. Some experiments were made at Dr. W. D. Hunter's suggestion to determine how long larvæ could survive exposure to water. Free larvæ with no protection whatever pupated and produced moths after being in water in tubes for 44 hours. Larvæ survived for several days after being in water longer, but none produced moths. Larvæ in cocoons survived 72 hours in water in tubes and free larvæ placed in pill boxes perforated with a needle produced one adult after 8 days' submergence in a pitcher. Pupæ did not survive as long as larvæ. Old bolls picked in January, 1918, and stored in the laboratory till April, 1919, were submerged in water and left floating on the surface of water in a trough. Larvæ pupated and produced adults after 7 days in both instances, but no adults emerged after 11 days in either case.

Several plants containing green bolls heavily infested were placed in the river and tied so that they could not float away. When there was enough current in the river to keep the plants floating at the end of the string the bolls were all washed away at the end of 4 to 5 days. When there was no current the plants sank to the bottom and all the larvæ were found dead in 3 days. It is quite likely, however, that when plants are allowed to float free and move with the current the bolls will remain on the plants longer. When floating in this manner part of the plants are always out of water and, as they revolve more or less, the same bolls will not be submerged all the time and larvæ will survive more than 3 days. To determine how long larvæ would live in green bolls, sample bolls were placed in a trough and examined daily. The bolls floated and larvæ lived for 10 days. On the eleventh day all of the bolls sank to the bottom and were very rotten, and no live larvæ were found in them. The results of these experiments are summarized in Table XVIII.

TABLE XVIII.—*Effect of water on pink bollworm larvæ.*

Condition of exposure.	Number treated.	Time of exposure.	Per cent killed.	Remarks.
		Hours.		
Loose larvæ in tube of water	5 larvæ	20	60	1 pupated afterwards.
	7 larvæ	44	70	2 pupated afterwards.
	20 larvæ and 3 pupæ	120	100	Larvæ lived several days.
	30 larvæ	144	100	
Loose cocoons in tube of water	10 larvæ	48	70	Heavy cocoons; 1 adult emerged.
	20 larvæ	72	90	Heavy cocoons.
	do	96	100	Do.
	10 larvæ	120	100	Do.
Double seed in tube of water	10 double seed (5 larvæ.)	96	100	
	10 double seed (3 larvæ.)	124	66	2 larvæ alive.
Seed and cocoons in pill boxes perforated with needle (3 seeds and 2 cocoons in each box. Counted together).	1 box	24	0	
	do	48	0	
	do	72	40	
	do	96	0	
	do	120	50	2 pupated afterwards.
		Days.		
	do	6.5	40	
	do	8	60	
	do	11	100	
	do	15	100	
	21 boxes	17	100	
Bolls floating on water in trough. (Bolls picked in December, 1918, and stored in laboratory. Contained many dead larvæ not included in count.)	20 bolls (29 larvæ)	7	80	Bolls covered with algæ and rotten.
	20 bolls (12 larvæ)	11	100	Do.
	20 bolls (56 larvæ)	14	100	Do.
	20 bolls (17 larvæ)	17	100	Do.
	120 bolls (273 larvæ)	18	100	Do.
Bolls submerged in water in trough (same kind of bolls as above).	20 bolls (30 larvæ)	7	77	2 pupated; bolls covered with algæ and rotten.
	20 bolls (113 larvæ)	11	100	1 larva lived several days; bolls rotten.
	20 bolls (46 larvæ)	14	100	Bolls rotten.
	20 bolls (14 larvæ)	17	100	Do.
	120 bolls (169 larvæ)	18	100	Do.
		Hours.		
Green bolls submerged in slatted box in river.	10 bolls (37 larvæ)	48	95	Bolls fermenting and very sticky.
	10 bolls	72	100	Interior bolls rotten.
	10 bolls	96	100	Badly rotted.
Plant with green bolls attached floating on surface of river, Sept. 13, 1919.	10 bolls (40 larvæ)	48	55	Bolls fermenting.
	9 bolls (19 larvæ)	72	98.4	Interior of bolls rotting.
	7 bolls (11 larvæ)	96	46	All of live larvæ found in two bolls which were not submerged.
		Days.		
143 green cotton bolls placed in container of water. Water changed daily.	20 bolls (122 larvæ)	3	7.3	
	20 bolls (125 larvæ)	4	3.1	All dead in two badly decayed bolls.
	20 bolls (133 larvæ)	5	6.3	Decaying.
	20 bolls (107 larvæ)	6	60.7	Some in bad state of decay.
	15 bolls (84 larvæ)	7	31.5	Do.
	16 bolls (73 larvæ)	8	38.8	Some bolls rather small and badly decayed.
	10 bolls (61 larvæ)	9	44.2	Bolls decaying rapidly.
	10 bolls (51 larvæ)	10	60.7	Some still floating; badly decayed.
	6 bolls (43 larvæ)	11	100.0	Badly decayed.
	6 bolls (29 larvæ)	12	100.0	Very rotten.

In general, it may be said that larvæ will live in bolls submerged in water or floating on the surface of the water till the bolls themselves are thoroughly rotten. This may be a week or more, depending upon the condition of the bolls. The old dried bolls and larvæ webbed up in bits of rubbish are particularly likely to carry an infestation a long distance, for they float more readily than green bolls. One of the large plantations was considering dividing their property into zones which would be planted in cotton only every third or fourth year in order to reduce the damage by the pink bollworm, but the danger of reinfestation by irrigation water was considered so great that it was not adopted.

NATURAL CONTROL.

From the data collected in 1918 and 1919, it is concluded that the maximum infestation and the maximum damage to the cotton of the Laguna have been reached by this time, except for slight yearly variations due to climatic conditions which may have some effect on the development of the pink bollworm and its attack on the cotton. It is the belief of the plantation owners that the damage or loss to the crop has remained about the same since 1916, or that the maximum had been reached at the end of five years from the time of introduction.

MORTALITY OF NEWLY-HATCHED LARVÆ.

It has been shown in Table III that 47.1 per cent of the pink bollworm eggs are not deposited on the squares or bolls. The larvæ from these eggs must crawl some distance before reaching food. In this migration they are readily attacked by insect enemies, are exposed to the hot sun, become weakened and exhausted, and eventually may succumb to starvation. It is thought that very few or possibly none of the larvæ from this 47.1 per cent of the eggs ever enter the squares or bolls. Many of the larvæ from the remaining 52.9 per cent of the eggs deposited on suitable parts of the plant never succeed in entering the bolls or squares either. To determine what percentage of the larvæ hatching from eggs deposited on the plants fail to enter the bolls or squares, five plants were examined. These records were carefully made. Every part of the plant was closely examined with a hand lens for eggs and eggshells. The larvæ, pupæ, and exit holes were also carefully counted and the mortality rate calculated from the number of eggshells found on the plants and the total infestation of the plants. The results are given in Table XIX.

TABLE XIX.—*Mortality of larvæ of P. gossypiella.*

Number of plants.	On plant.		Number of larvæ.		Pupæ found.	Exit holes.	Larvæ, pupæ, and exit holes.	Per cent mortality.	Remarks.
	Number of shells.	Number of eggs.	In squares.	In bolls.					
1.....	181	89	3	17	0	7	27	85.1	
1.....	141	111	1	46	0	12	59	58.2	
1.....	190	115	6	84	0	24	114	40.0	
1.....	170	53	0	25	3	13	41	75.9	16 bolls on plant.
1.....	103	143	2	39	0	15	57	44.7	28 bolls on plant.
5.....	785	511	12	211	3	72	298	62.1	

From this table it is seen that the mortality varies from 40 to 85.1 per cent with an average of 62.1 per cent. If it is assumed that none of the larvæ from the 47.1 per cent of the eggs laid on other parts of the plants ever succeed in entering the bolls or squares, this would still leave 15 per cent of the larvæ from eggs laid on the squares and bolls unaccounted for. Since many eggshells had undoubtedly fallen from the plants examined, this percentage of mortality (62.1 per cent) is smaller than what actually occurs.

To determine what percentage of the eggs laid on the bolls are lost, 16 samples of 25 green bolls each were examined, the number of eggs laid on them counted, and the total infestation found (Table XX).

TABLE XX.—*Mortality of pink bollworm larvæ from eggs laid on bolls.*

Number of bolls.	Eggs.			Larvæ.				Exit holes.	Pupæ.	Total infestation.	Per cent of larvæ from eggs laid on bolls recovered in bolls.
	Tip.	Base.	Total.	First.	Second.	Third.	Fourth.				
400..............	61	4,958	5,019	190	347	442	1,005	386	1	2,371	45.8
Average..........	0.15	12.4	12.5	0.47	0.87	1.1	2.5	0.96	......	5.92	....

There were 5,019 eggs and eggshells on the bolls. If larvæ from all these eggs had hatched and all the larvæ gone into the bolls, there would have been an average infestation of 12.5 larvæ per boll, whereas an average of a little less than 6 larvæ was actually found. These examinations were made in October and later examinations showed that the maximum infestation ever reached was an average of 7 per boll.

These figures indicate that about half of the larvæ from eggs laid on the bolls themselves never succeed in entering them. In Table III it was shown that 51.7 per cent of the eggs were laid on the bolls and appendages, and if only half of these successfully enter the bolls this would be equal to 25.8 per cent of the total eggs. This loss of

25 per cent, in addition to the 47.1 per cent laid on other parts of the plants and assumed to be lost, would bring the total mortality of young larvæ up to 72.9 per cent. This figure (72.9 per cent) is thought to approach more closely what actually takes place in the field than that of 62.1 per cent based on the number of empty shells found. This is borne out by laboratory experience where the mortality was 90 per cent or more.

Once the larvæ are inside the bolls there is very little or no mortality during the summer months.

MORTALITY OF HIBERNATING LARVÆ IN THE FIELDS.

There is a very heavy mortality in hibernating larvæ left in the fields during the winter, especially when the fields are irrigated. Examinations of old bolls picked up in the fields showed that about 80 to 90 per cent of the larvæ survived till February, and that the mortality rapidly increased from this date onward. The mortality varies greatly in different samples, but by the end of March it is difficult to find any live larvæ in the scraps picked up on the ground in the fields. There are still live larvæ present, but the old bolls have broken up, scattered, and in cultivated fields are difficult to find. On March 13, 1918, only 3 live larvæ were found from a bushel of old bolls and trash picked up in a lightly infested field at San Pedro. On April 16, 1919, no live larvæ were found in the old bolls left on the ground after cattle had grazed over the fields at Tlahualilo, but about 5 per cent were still alive in the bolls left on the stalks.

To secure more data on this point, two series of experiments were started on November 26, 1918. One experiment was under as nearly normal irrigated field conditions as possible and the other under nonirrigated conditions. The fields in the Laguna are usually irrigated in November, December, or January, when cotton follows cotton, as it does on most plantations. When fields have been lying fallow for a season, the water is applied any time during the year when it is available. About 3 feet of water is placed on the fields and allowed to soak in. This requires from one to several months, depending upon the character of the soil. In the experimental plot irrigation was started on December 2 and continued till December 8, when the motor burned out. Water was again applied on December 23, 1918, and continued daily until January 22, 1919. On account of the small amount of electric current available, the plot could not be filled 3 feet deep, but the daily application of a few inches of water kept the ground thoroughly wet and covered with water at least part of each day.

In each of the series the larvæ were exposed under wire cages in bolls in a single layer on the surface of the ground, in bolls buried 6 to 7 inches deep, and in double seed buried one-fourth inch deep in flowerpots which were set in the soil flush with the surface. Moreover, larvæ removed from all seed and lint were placed in screened boxes and flowerpots and allowed to enter the soil. These were also buried flush with the surface of the ground. A sample of the bolls used was examined at the time and found to contain an average of 6.64 fourth-instar and 0.03 third-instar larvæ per boll. The material was examined at different dates and the results are given in Table XXI.

TABLE XXI.—*The mortality among hibernating Pectinophora gossypiella larvæ under different field conditions.*

Experiment No.	Conditions of exposure.	Examination.					Remarks.
		Date.	Live larvæ.	Dead larvæ.	Live pupæ.	Pupal skins.	
		1919.					
557	300 larvæ removed from seed and lint and buried in wooden box of soil in irrigated plot.	June 11	0	2	0	0	61 empty dirt cells around side of box.
558A	50 larvæ in flowerpot, same as 557.	May 10	0	Several.	0	0	
558C	Same as 558A	June 10	0	3	0	0	
558B	Same as 558A	June 11	0	0	0	0	
558D	50 double seeds buried in flowerpot on irrigated plot.	June 11	0	0	0	0	Seed well rotted.
560	300 larvæ removed from seed and lint and buried in wooden box of soil in nonirrigated plot.	June 12	12	....	3	2	Larvæ webbed up on side of box.
561A	50 larvæ in flowerpot, same as 560.	May 10	28	1	1	1	Larvæ in cocoons.
561B	Same as 561A	June 11	0	7	0	0	
561C	50 double seeds in flowerpot on nonirrigated plot.	June 12	6	....	1	3	Seed well rotted.
559A	200 green and dry bolls buried 6 to 7 inches deep on irrigated plot.	Mar. 10 (10 bolls).	0	65	0	0	Bolls rotting badly.
		Apr. 24 (10 bolls).	0	48	0	0	Very rotten and fallen to pieces.
		May 16 (50 bolls).	0	....	0	0	Fallen to pieces.
		June 6 (130 bolls).	0	....	0	10	Bolls so rotten difficult to pick from soil.
559B	200 green and dry bolls left on top of ground on irrigated plot.	Mar. 10 (10 bolls).	39	29	0	0	Bolls in good condition.
		Apr. 24 (10 bolls).	20	36	1	3	Do.
		May 15 (50 bolls).	74	194	2	2	Some of bolls getting rotten, but those which had opened when experiment began still in good condition.
		June 4 (116 bolls).	51	344	6	18	
562A	200 green and dry bolls buried in soil 6 to 7 inches deep on nonirrigated plot.	Mar. 11 (10 bolls).	52	0	0	0	Bolls badly rotted.
		Apr. 24 (10 bolls).	13	13	2	10	Badly rotted and could not separate bolls.
		June 7 (180 bolls).	0	0	0	0	Thoroughly rotten.
562B	200 green and dry bolls left on top of ground on nonirrigated plot.	Mar. 11 (10 bolls).	68	26	0	0	Bolls in very good condition.
		Apr. 24 (10 bolls).	54	28	0	0	Do.
		May 15 (50 bolls).	83	137	0	6	Do.
		June 7 (50 bolls).	152	188	2	11	Do.
		July 25 (25 bolls).	0	100	0	7	Do.
		Aug. 22 (80 bolls).	0	0	0	0	Do.

Table XXI shows that no live larvæ were found during May and June among those removed from seed and lint or in double seed buried in the irrigated plots (Experiments Nos. 557 and 558 A to D), and that 12.8 per cent were alive or had emerged as moths under the same conditions in the nonirrigated plot (Experiments Nos. 560 and 561 A to C). No live larvæ were found in bolls buried in irrigated plots from March 10 (the first examination) until June 6 in Experiment No. 559 A, and none in bolls buried in nonirrigated plot (Experiment No. 562 A) after April 24. The surrounding soil had been irrigated and when the last examination was made on June 7 the soil in the nonirrigated plot was found moist about 3 inches below the surface from water that had seeped in from below. From this experiment 6.2 per cent survived till April 24. There was less mortality in the bolls when left on the surface of the ground than when buried. In the irrigated plot (Experiment No. 559 B) live larvæ were found in bolls left on the surface of the ground at the last examination on June 4, 1919, and 9.7 per cent had survived or previously emerged as moths on this date. On the nonirrigated plot (Experiment No. 562 B) 50 per cent of the larvæ in bolls on the surface were alive on June 7, 1919. At the next examination, on July 25, all of the larvæ were dead.

In all of the experiments, especially the later examinations, many of the larvæ were not recovered because the dead larvæ were so decomposed they were not recognizable. Very few if any escaped, for the buried bolls had close-mesh wire screen over the top and along the sides, extending below the level of the bolls. The earth surrounding the material was carefully sifted and larvæ and pupal skins found here counted with the others. The percentages of mortality for the bolls are based on the number of larvæ found in the samples at the beginning of the experiments. This is not absolutely accurate, because the number of larvæ may vary considerably in individual bolls, but it is the most reliable figure to use inasmuch as the actual number of dead larvæ could not be determined.

It is seen that the mortality increases as the season advances, even where the conditions were most favorable, no live larvæ being found as late as July 25, and that the mortality in all the experiments was greater when the larvæ were buried than when they were left on the surface, and greater when the plots were irrigated than when left dry. These experiments also show that the greatest danger for starting a new infestation from material left in the fields is the old bolls left on the surface of the ground. Over 9 per cent of the larvæ in these bolls on the irrigated plot survived till June 4 and 50 per cent survived in the nonirrigated plot. At this season the cotton will be large enough for oviposition to begin. Under the usual field conditions the irrigated lands will have been cultivated before this date and the mortality increased by breaking up and burying the bolls. On the other hand, the bolls float on water and the wind frequently blows them against the borders on one side of the field, where they are piled up several inches or more deep. This concentration keeps some of the bolls out of the water and affords more protection for the bolls in the interior of the pile against heat and cold. If the fields are not irrigated it means they will not be planted the following year and such fields are usually grazed by goats, cows, and burros, which eat many of the bolls.

Whether or not the results obtained in these experiments during only one winter[5] hold true for what actually takes place in the Laguna it is impossible to say, but they indicate beneficial results from irrigation and burying the bolls. That a very heavy mortality, probably more than 95 per cent, does take place in the fields is shown by field examinations of the bolls and the very light infestation in the early part of the season. There are such enormous numbers of larvæ hibernating in the fields that the crop would be entirely destroyed if the mortality was not very high.

Willcocks (7) in Egypt left bolls out of doors exposed to the sun on the surface of dry ground and ground that was watered periodically (three waterings). He found a very high mortality during April, May, and June, and all the larvæ were dead on June 25. There was a slightly higher mortality among the larvæ in the watered bolls and all the larvæ were dead on April 8, while some survived in the dry bolls till May 3. His figures "most certainly show that the chance of resting-stage pink bollworms surviving in the bolls fully exposed to the sun on the surface of dry sheraki land in May, June, and July is a remote one." He buried another lot of bolls on November 24 in damp soil in boxes. Some of these were kept dry and others wet. Some were stored indoors and others outdoors, though none were in direct sunlight. There was less mortality in the buried bolls than in those left on the surface exposed to the sun, and he says, in speaking of wet conditions, "this does not seem to be materially disadvantageous to the pest." In all of the buried bolls there was a decided emergence of the larvæ to the top of the soil, which began as soon as the bolls were buried (November 24) and continued intermittently in some cases where the bolls were kept dry till the following November. Water hastened this larval emergence when applied in the fall or the following spring, but though the bolls were badly rotted the larvæ were still able to remain in them, and spun up in their almost water-tight cocoons during March, April, and May.

In our experiments in Mexico, larvæ survived better in bolls on the top of the ground than when buried and better when left dry than when irrigated. In Mexico the temperature was never as high

[5] These results were substantiated by experiments during the winter of 1919–20.

as it is in Egypt in May and June (107° and 111° F.) and our bolls received some protection from the sun by the screen covering of the irrigated bolls and the cheesecloth covering over the nonirrigated bolls. Furthermore, our bolls were probably kept wetter during the 30 days when they were wet than Willcocks's were, but his were kept wet for a longer time. There was but very little larval emergence in any of our bolls. This is shown by the large numbers of dead larvæ found *in situ* in the earlier examinations, when they were still recognizable, and by the few larvæ or pupal skins found in the surrounding soil. There was more larval emergence from the bolls in the irrigated plots where 12 pupal skins were found in the soil than in the nonirrigated where only 2 or 3 were found. About half of the larvæ recovered in the bolls were in the lint, but no count was kept of this point and it is not known whether there were more than are usually found in lint in the bolls in the fields during the fall or not. In the case of the double seeds in the irrigated plot the following note was made: "Earthen cells were noticed in a few instances, apparently some of the larvæ left the seed." In the double seed on the nonirrigated plot 4 pupal skins were found in the soil.

On March 11, 1919, 100 bolls which were picked on December 7, 1918, and stored in the laboratory till this date were buried 1 to 2 inches deep in a box of soil and wet thoroughly. The box was sprinkled often enough to keep it thoroughly wet for 30 days. On April 11 the contents were carefully examined and 35 live larvæ and 90 dead larvæ were found in the bolls and only 4 larvæ and 2 pupæ in the soil. Willcocks (7) found a very sudden increase in the number of larvæ emerging to the surface in a box of bolls buried in dry soil and watered in the spring.

Unfortunately a sufficiently large sample of bolls for our check was not examined at the beginning of the experiment to determine the mortality until this date, and the check sample examined at the end of the experiment contained more live larvæ than at the beginning. The indications were, however, that the treatment had killed a large number of the larvæ. The bolls were totally rotted and larvæ which were dead at the beginning of the experiment were unrecognizable at the finish.

MORTALITY OF HIBERNATING LARVÆ IN STORED SEED.

The number of larvæ found in the ginned seed is very small compared to the number found in the bolls when the cotton is picked. In the Laguna the seed cotton is passed through cleaners or beaters before it goes to the gins to remove the trash and dirt. This causes most of the larvæ to leave the lint and many are undoubtedly driven from the seed also during the process. Larvæ are thrown out by the thousands with the trash that comes from the later pickings, and in some cases the pile of trash and the sides of surrounding buildings are pink with crawling larvæ. Many of the double seeds are torn apart in the cleaner and gin, though some go through unharmed. It is extremely disappointing to look for larvæ in seed which comes from heavily infested cotton. In such seed in the winter or spring one can rarely collect more than 75 to 100 live larvæ in the course of an eight-hour day. Ten samples of 2,500 seeds each were taken on different occasions during February and March, 1918 and 1919, from seed houses, examined seed by seed, and only 9 live larvæ were found.

For our rearing work larvæ were removed by hand from the bolls and placed in fruit jars with seed to pass the winter. Table XXII shows that the mortality among larvæ removed from bolls in November and stored in the laboratory during the winter of 1918 and 1919 was 22.6 per cent and that 0.4 per cent were still alive November 20, 1919, when the work was discontinued.

Other larvæ were disturbed as little as possible and were left in the double seed where they had prepared to spend the winter. The double seed were picked from the lint by hand and stored in the laboratory under the same conditions as the others. Table XXIII shows that there was 16.2 per cent mortality among larvæ in double seed and that 4.4 per cent were still alive on November 20, 1919.

TABLE XXII.—*Mortality among larvæ removed from bolls and kept in the laboratory in a condition as near to that of stored seed as possible.*

Date collected.	Number entering resting stage.	Number emerged.	Per cent mortality.	Per cent emerged.	Number alive Nov. 20, 1919.
1918.					
Sept. 30	83	71	13.2	85.5	2
Nov. 13	281	191	31.6	68.0	2
Do	256	180	28.9	70.3	2
Do	269	153	43.1	56.9	0
Nov. 14	260	183	29.7	70.3	0
Nov. 15	282	220	22.0	78.0	0
Do	309	255	17.5	82.5	0
Do	239	201	15.4	84.1	1
Do	320	255	19.6	79.6	2
Do	299	244	17.7	81.6	2
Do	277	211	23.4	76.2	1
Nov. 16	260	193	25.0	74.2	2
Do	244	192	20.9	77.7	1
Nov. 17	265	242	8.6	91.3	1
Nov. 19	125	99	20.8	79.2	0
Total	3,769	2,890			16
Average			22.6	77.0	0.4 per cent.

The moths were removed daily and a record kept for each jar. The percentages used are based on the number of moths emerging and the number of dead and live larvæ found in the jar at the end of the experiment. As these larvæ were carefully removed by hand and stored indoors, the mortality was the minimum that can be expected and is much lower than in seed ginned and handled on a commercial scale. It is difficult to determine the mortality in the seed warehouses, because the dead larvæ are so hard to find, but it is evident to one collecting larvæ that it is much higher in the early spring than in the fall. The mortality was 80 per cent among larvæ thrown out by the cleaners and stored indoors during the winter, and in this sample only the most active larvæ were used.

TABLE XXIII.—*Mortality among larvæ in double seeds removed from lint by hand and stored in jars in the laboratory.*

Date collected.	Number entering resting stage.	Number emerged.	Per cent mortality.	Per cent emerged.	Number alive Nov. 20, 1919.
1918.					
Nov. 15	206	182	8.7	88.3	6
Nov. 22	190	165	9.4	86.8	7
Nov. 23	184	157	8.1	85.3	12
Nov. 22	88	76	9.0	86.3	4
Do	61	41	22.9	67.2	6
Dec. 25	213	119	41.3	55.8	6
1919.					
Jan. 23	172	143	11.6	83.1	9
Total	1,114	883			50
Average			16.2	79.2	4.4 per cent.

MORTALITY OF LARVÆ PLANTED WITH THE SEED.

A screen-wire cage was built so that no infestation could interfere from the outside, and 100 double seeds were planted with sound seed in 30 hills to see what the infestation would be from larvæ planted with the seed alone. No infestation occurred during August, but from September 1 to November 7 the infestation went from 12 per cent to 96 per cent, with an average of 5.6 larvæ per boll on November 7. Thus it is evident that should all the larvæ left in the fields be destroyed either naturally or by artificial means, the infestation arising from the larvæ planted with the seed alone is sufficient to cause a considerable loss (Table XXIV).

TABLE XXIV.—*Infestation of pink bollworm from 100 double seeds planted in a cage.*

Date examined.	Per cent of bolls infested.	Average infestation per boll.			
		Larvæ.	Pupæ.	Exit holes.	Total.
1919.					
Aug. 1	0	0	0	0	0
Aug. 6	0	0	0	0	0
Aug. 22	0	0	0	0	0
Sept. 1	12.00	0.12	0	0	0.12
Sept. 30	84.00	2.20	0	0.96	3.16
Nov. 7	96.00	5.60	0	0	5.60

PARASITES AND PREDATORS.

What part of the mortality in the newly hatched larvæ is due to starvation, exposure to the sun, or falling from the plants, and what to predacious insects, could not be determined, but the toll taken by the nymphs and adults of three species of small undetermined Hemiptera is evidently very high. The attacks on the small pink bollworm larvæ from these predators are so important that daily examinations of all food placed in the breeding cages was absolutely necessary. Often one small nymph would destroy the larvæ from a large number of eggs during the night.

The larvæ of a lace-wing, *Chrysopa rufilabris* Burm., attacks the newly hatched pink bollworm and also the larger larvæ in the flowers.

Only very rarely is a dead larva found inside a boll. The feeding habits within the green boll greatly reduce the chances of attack by parasites and predators during this period. When the exit holes are cut, or the boll begins to open, or when the larvæ are migrating to the ground, they are exposed to these enemies for a short time. This short period of exposure may account for the very few parasites found. Only three species and one specimen of each were found attacking the larvæ. They were the Hymenoptera *Habrobracon* sp., *Parisierola emigrata* Rohwer, and a small dipteron, *Tortriciophaga tortricis* Coquillett. The scarcity of these parasites during the two years proves very conclusively that no relief can be hoped for from this source.

The pupæ of the pink bollworm in Mexico were not attacked by parasites, so far as our observations show.

The small chalcid *Trichogramma minutum* Riley may prove beneficial in parasitizing the eggs of the pink bollworm, but it was not observed attacking the eggs until late in the season, and then only very rarely.

An outbreak of mites, *Pediculoides ventricosus* Newport, occurred on the hibernating larvæ in the laboratory in 1918. Steps were taken immediately to check them by burning all infested material. To what extent these mites occur in the seed houses was not determined.

REPRESSION.

FUMIGATION OF SEED.

From the known instances in which infestations have occurred from larvæ planted in the seed there can be no doubt of the danger of planting infested seed. Several methods of killing the larvæ in the seed have been used in Egypt and other places (*10*), but all fall into three classes: Immersion of the seed in some substance to kill the larvæ, treatment with heat, or fumigation with poisonous gases. Immersion of seed in liquids is obviously out of the question where tons of seed are used for planting on a plantation. In Egypt larvæ can be killed by exposing them to the heat of the sun. Preliminary experiments showed that the temperature in Mexico during the planting season was not high enough to kill the larvæ and that cotton seeds are very poor conductors of heat. Machines (*4*, *6*) have been perfected for passing the seed on an endless belt through air heated to 130° F. and houses have (*7*) been constructed for heating a mass of seed sufficiently high to kill the larvæ, but in Mexico fuel is scarce and very expensive, so fumigation with poisonous gases seemed the most economical and practical method to use.

A fumigation chamber of adobe bricks set in mud, the usual type of building in the Laguna, was constructed. The walls of this chamber were about 20 inches thick and were plastered on the inside and outside with cement. The floor was of brick set in mortar. During the fumigation the wooden door was closed and several thicknesses of wall paper plastered over the cracks. The size of the room was 5 by 8 by 10 feet, or 400 cubic feet. Three tons of cotton seed filled it about 5 feet deep. Experiments were made with seed placed in the room in bulk and in sacks. Carbon disulphid and hydrocyanic-acid gas were used.

Carbon Disulphid.

Live larvæ, pupæ, and adults were placed at different depths in the seed, usually near the top, center, and bottom of the pile. The use of adults was discontinued after the first few experiments on account of the death of all the moths, while in the same experiments the mortality of the larvæ varied a great deal. Pupæ did not seem more difficult to kill than larvæ. Larvæ, and pupæ when they could be obtained, were placed in single, double, and triple pill boxes, at least 60 larvæ and sometimes more being used for each experiment. Larvæ in double and triple boxes were thought to be about as difficult to kill as larvæ webbed up in seed would be. Sometimes the larvæ would spin cocoons in the boxes before they were placed in the house, but such larvæ were killed along with the others. Where only a few larvæ were not killed they were always in the triple boxes on the bottom of the pile.

As only one lot of 3 tons of seed was available, the seeds were taken from the house and left exposed to the sun for several days after each experiment. When the seeds were returned to the house the boxes of larvæ were tied in a muslin bag and placed in position, the disulphid placed in shallow vessels on the top of the seed, and the door sealed.

Considerable difficulty was experienced at first in determining whether larvæ were dead or not. All of the larvæ would appear dead when removed, but they still retained their pink color and some of them would revive and pupate after lying in a comatose state for a week or more. Later all the larvæ were kept until we were absolutely sure whether they were dead or alive. Table XXV is a detailed account of the fumigations that were made with carbon disulphid.

TABLE XXV.—*Preliminary fumigation experiments with carbon disulphid for P. gossypiella in cotton seed.*

Experiment No.	Dosage. Pounds.	Dosage. Cubic feet.	Length of exposure.	How seed was stored.	Location of larvæ.	Per cent killed in each location.	Total per cent killed.
			Hours.				
1	1	102	90	In sacks	Top sack	100	100
					Bottom sack	100	
2	1	161	48	do	Top sack	100	100
					Bottom sack	100	
3	1	289	48	do	Top sack	0	0
					Bottom sack	0	
4	1	161	23	do	Top sack	12	14
					Bottom sack	16	
5	1	161	23	do	Top sack	60	43
					Bottom sack	26	
6	1	161	48	In bulk	2½ feet deep	100	60
					4½ feet deep	20	
7	1	103	48	do	2½ feet deep	100	72
					4½ feet deep	45	
8	1	124	48	do	2½ feet deep	31	16
					4½ feet deep	0	
9	1	82	48	do	2½ feet deep	100	88
					4½ feet deep	75	
[1]10	1	54	24	do	2½ feet deep	100	90
					4½ feet deep	80	
11	1	80	42	In bags	On top	100	100
					In center	100	
					On bottom	100	
13	1	100	1 week.	In bulk 6 feet deep.	On top	100	91
					2 feet deep	100	
					4 feet deep	84	
					6 feet deep	82	
			Hours.				
19	1	100	48	In bulk 5 feet deep.	18 inches from top	100	94
					Middle	97.5	
					Bottom	75	
20	1	80	48	do	Middle	100	100
					Bottom	100	
21	1	80	48	do	Middle	100	100
					Bottom	100	
22	1	80	48	do	Middle	100	100
					Bottom	100	
23	1	80	24	do	Bottom	100	100
26	1	80	12	do	Middle	100	95
					Bottom	90	
27	1	80	15	do	Middle	85	82.5
					Bottom	80	
29	1	85	24	do	Middle	100	100
					Bottom	100	
30	1	85	24	do	Middle	100	100
					Bottom	100	
31	1	90	24	do	Bottom	85	85
32	1	90	24	do	do	60	60

[1] In Experiment No. 10 the larvæ were placed in glass tubes, which were closed with cork stoppers, making them approximately air tight.

In experiments 20, 21, and 22 all larvæ were killed with 1 pound of disulphid to 80 cubic feet in 48 hours. In order to shorten the time, experiments 23, 26, and 27 were made, and all the larvæ were not killed. All of the disulphid had not evaporated at the end of 12 and 15 hours in experiments 26 and 27, but it had evaporated in experiment 23 in 24 hours, and all the larvæ were killed, showing that 24 hours are necessary to evaporate and to secure maximum penetration of 1 pound of disulphid in 80 cubic feet. This was in the summer time, when the temperature inside the house was 75° to 80° F. Experiments 13, 19, 29, and 30 were made to decrease the dosage needed. All larvæ were not killed in experiments 13 and 19, where the dosage was 1 pound disulphid to 100 cubic feet with long exposures, but all were killed in experiments 29 and 30, with 1 pound to 85 cubic feet and a 24-hour exposure.

Table XXVI is a summary of the carbon disulphid experiments. From these experiments it is seen that satisfactory results were obtained by using 1 pound of carbon disulphid to 80 cubic feet for 24 hours or longer when the seeds were not over 5 feet deep.

TABLE XXVI.—*Fumigation of cotton seed with carbon disulphid.*

Experiment No.	Dosage.		Exposure.	Per cent larvæ killed.	How seeds were placed.
	Pounds.	Cubic feet.			
			Hours.		
1	1	102	90	100	Seed in bags.
2	1	161	48	[1]100	Do.
11	1	80	42	100	Do.
20	1	80	42	100	Seed in bulk, 5 feet deep.
21	1	80	48	100	Do.
22	1	80	48	100	Do.
23	1	80	24	100	Do.
29	1	85	24	100	Do.
30	1	85	24	100	Do.
26	1	80	12	95	Do.
19	1	100	48	94	Do.
13	1	100	168	91	Seed in bulk, 6 feet deep.
10	1	54	24	[2]90	Seed in bulk, 5 feet deep.
9	1	82	48	88	Do.
31	1	90	24	85	Do.
27	1	80	15	82.5	Do.
7	1	102	48	80.5	Do.
32	1	90	24	60	Do.
6	1	161	48	51	Do.
5	1	161	23	37	Seed in bags.
8	1	124	48	17	Seed in bulk, 5 feet deep.
4	1	161	23	13.3	Seed in bags.

[1] Record doubtful. [2] Larvæ in corked vials.

HYDROCYANIC-ACID GAS.

The fumigation of cotton seed with hydrocyanic acid gas proved very unsatisfactory, as the gas is so light that it will not penetrate the seed more than a few inches. In some of the experiments an earthenware crock containing the sulphuric acid was set directly on top of the seed pile and the cyanid lowered by a string from the outside in the usual way. The penetration was so poor that a special generator was designed. A section of 10-inch pipe 14 inches long was fitted with gas-tight caps on both ends and a lead inner pot to hold the acid. The generator was placed outside the house below the floor level and the gas conducted to the inside, where it was allowed to escape in the bottom of the fumigation chamber through perforated pipes. It was hoped that the penetration upward would be greater than downward, but there was very little difference.

Table XXVII is a summary of the experiments with the use of hydrocyanic-acid gas. From these experiments it is seen that it is not practicable to use hydrocyanic-acid gas when the seeds are over 4 inches deep. It could not be recommended even when seed is in ordinary bags, for the center of a bag of cotton seed is more than 4 inches from the surface of the sack exposed.

TABLE XXVII.—*Fumigation of cotton seed with hydrocyanic-acid gas.*

Experiment No.	Position of generator.	Dosage per 100 cubic feet.	Exposure.	Per cent of larvæ killed.	Remarks.
			Hours.		
17	Inside	2–2–4	2	100.0	Seed in bulk, 4 inches deep.
24	......do	4–4–8	3	70.0	Seed in bulk, 6 inches deep.
18	......do	2–2–4	2½	62.5	Do.
25	......do	2–2–4	2	60.0	Do.
16	......do	4–4–8	24	47.0	Seed in bulk, 5 feet deep; all not killed 6 inches deep.
15	Outside	4–4–8	24	34.0	Seed in bulk, 5 feet deep; none killed 2½ inches deep.
14	......do	2–2–4	24	10.0	Seed in bulk, 4½ feet deep; all not killed 1 foot from floor.
12	Inside	2–2–4	48	.6	Seed in bulk, 5 feet deep.

POISONING EXPERIMENTS.

As a possible means of controlling the pink bollworm in the field, poison experiments were conducted in the laboratory with both adults and larvæ. Moths readily drink water in captivity when it is sprayed on the leaves or blotting paper in the breeding jars, and it was thought they might be killed by poisoning the drinking water with an arsenical solution. Repeated trials were made by using a solution of calcium arsenate for the moths to drink. The longevity of these moths was the same as that of those in the check, where pure water was used.

While the laboratory experiments in poisoning the adults were not encouraging, it was thought advisable to try it under field conditions. From the habit of the newly hatched larvæ of crawling over the plants and bolls before they enter, theoretically it seemed possible that a large number of young larvæ might be poisoned.

Average plats were selected at San Isidera, Tlahualilo, and at the laboratory for poisoning the plants. Weekly applications of powdered calcium arsenate were made with hand dusters. These applications were begun about July 15 and continued until the last week in October. The gauges on the machines were opened to their fullest extent and as heavy an application as possible was made each time. (Table XXVIII.)

TABLE XXVIII.—*Weekly examination of bolls from poison experiments: Average number of larvæ per boll.*

Week ending—	Tlahualilo.				San Isidero.		Lerdo.	
	Zaragosa.		Small experiment.					
	Poison.	Check.	Poison.	Check.	Poison.	Check.	Poison.	Check.
Aug. 2	0.05	0.13	0.6	0.66	0	0	0.62	0.62
Aug. 9	.11	.09	.6	.44	0	0	.80	.80
Aug. 16	.26	.23	.42	.46	.02	0	3.50	3.88
Aug. 23	.31	.38	.88	.32	.04	.05	4.34	3.14
Aug. 30	.57	.88	1.2	1.6	.02	.03	4.16	3.52
Sept. 6	1.2	.86	1.7	3.0	.14	.06	2.8	2.7
Sept. 13	1.8	5.10	2.3	2.6	.20	.10	4.6	4.8
Sept. 20	1.83	1.50	3.2	2.6	.25	.14	....	....
Sept. 27	1.45	5.10	1.2	1.1	.27	.28	6.28	5.84
Oct. 4	5.77	6.90	2.4	3.4	1.50	2.30	....	....
Oct. 11	6.40	8.40	4.0	4.5	3.70	3.0	....	....
Oct. 18	7.60	8.10	4.2	5.0	5.50	5.30	6.48	....
Oct. 25	7.20	5.50	6.0	5.7	8.00	....	....	....
Oct. 31	8.70	9.80	3.9	4.0	7.00	5.10	5.70	5.60

Weekly examinations of bolls both from the poisoned and check plats were made. The average number of larvæ per boll varied slightly. These variations, however, occurred in other samples of bolls where no poison was used and the poisoning did not check the infestation. The season of experiments was unfavorable for poisoning experiments. There was about twice the normal rainfall, which washed the poison from the plants, and, moreover, caused the cotton to grow so rank that it was impossible to get a thorough application with the available labor. Under more favorable conditions it is possible that better results might be obtained.

TRAPS.

TRAP LIGHTS.

In the laboratory, where the doors and windows were screened and the moths could not escape, they would frequently come to the electric lights, resting on the shade or wall near by, but under outdoor conditions moths would seldom come to lights. Acetylene and electric lights were suspended repeatedly in front of a white background in the laboratory cotton plats, where there were thousands of moths. In the course of 2 or 3 hours not more than 6 to 8 moths would come to the lights, while at the same time an examination with a flashlight would show there were large numbers on the plants only a few feet away. The few that did come to the lights were probably ones that we disturbed in moving about, and it can not be said there was any attraction whatsoever to the lights.

An electric trap light was also placed within a few feet of the plants, with negative results. Another trap light was run all night for 15 consecutive nights in an open shed where there were hundreds of tons of seeds and only 5 moths were taken. During the same 15 nights large numbers of moths were emerging from material at the laboratory which had been taken from this same shed a few weeks before, and it is certain that large numbers of moths were emerging in the seed shed while the trap was in operation. Light traps have been recommended as a means of control by several people. Gough (*12*), Willcocks (*7*), Ballou (*11*), and others report catches of thousands of moths per night in light traps. Ballou (*11*) found that most of the moths came to the light in the hour following sunset. Some authors found lights so attractive to the moths that they were used to determine the number of moths emerging from stored material, but in Mexico we found that practically none came to the lights. Busck (*8*) in Hawaii also found that the pink bollworm moths were not attracted to lights.

Attraction to Fruit.

Cone-shaped traps of the type used for flies were baited with oranges, bananas, apples, mangoes, guavas, and pineapples and were repeatedly exposed among the cotton plants with absolutely negative results.

RECOMMENDATIONS FOR CONTROL.

Too much can not be said and done in encouraging the destruction of hibernating larvæ. They are the source of infestation for the following year. If 9 per cent or less of the larvæ are able to survive the natural mortality of winter and early spring in irrigated fields, this small percentage, with the larvæ surviving in the seed and other places, produces an infestation the following year that causes approximately 25 per cent gross loss to the Laguna crop. Every hibernating larva killed during the winter or early spring before oviposition begins means the cutting off of many thousand larvæ by the end of the season. The paramount necessity, then, is to reduce the survival of hibernating larvæ to as low a figure as possible.

Burning of Old Stalks and Bolls.

Just as soon as possible the stalks should be cut and raked up in piles. Old bolls, sticks, and trash of all descriptions to which larvæ may be attached should be carefully picked up and burned with the the stalks, the main object being to burn everything in the field that contains larvæ or would be likely to afford protection for hibernating larvæ. If possible, the cutting and piling of the stalks should be done while the plants are still green, in this way minimizing the labor and increasing the effectiveness of the operation. Green stalks will retain most of their bolls, which shatter when they are cut dry. Just as soon as the piles lose their green color and become more or less dry they should be burned. Better results can be gained by waiting for this drying to take place rather than by burning the plants while they are yet green. Ordinarily the old stalks are cut and burned in the Laguna when preparing the land for the new crop. While this is done for purely agricultural reasons to make plowing easier, large numbers of live hibernating larvæ are killed. On the experimental plot at Lerdo the stalks were cut on the last day of February and examined during March. At this examination live larvæ at the rate of over 5,000 per acre were found in the bolls attached to the stalks. So many bolls had fallen or were knocked off during the cutting and piling that over half were left on the ground. A little extra effort in collecting and destroying these is well worth while. No boll or piece of cotton is so small or negligible that it should not be picked up and burned.

Cutting Stalks and Fall Plowing.

Experiments have shown conclusively that the mortality is greater in hibernating larvæ buried in the soil than in those left on top of the soil and greater in those buried in irrigated soil than in those buried in dry soil. It has also been found that the most favorable of all places for larvæ to hibernate under field conditions are the old bolls left undisturbed on standing stalks. During the winter of 1919–20 100 larvæ per 100 bolls successfully passed the winter on old stalks left standing in the fields and were alive on July 12, whereas only 4 larvæ per 100 bolls were found alive on this date in bolls lying on top of the soil. These facts suggest certain agricultural practices that can be used to good advantage in reducing the number of surviving larvæ.

Ordinarily the old stalks are not left standing in the fields, but on some plantations large acreages which are not to be cultivated the following year are left, and on others where "zoca" is produced the stalks are not cut till late spring or summer. All fields should be gone over with a stalk-cutter as early as possible, and in many cases the small amounts of cotton which are picked during the winter and spring could profitably be sacrificed in order to do this earlier in the season. Fall and winter plowing to cover the bolls is recommended whenever it is possible, and water should be applied in years when there is an excess.

Pasturing.

If it is not possible to cut and burn the stalks or plow the field in the above manner, owing to labor shortage, weather conditions, or other causes, it is a very good idea to graze the fields. Cattle, goats, and burros will eat the majority of the bolls on the stalks. One important drawback to the grazing plan is that there is a certain amount of infested material tramped into the ground. In one field near the town of Tlahualilo where the animals had been concentrated, only about one boll per square yard was found on the ground. In other fields that had been grazed, but not so thoroughly, an average of 5 or 6 bolls per square yard was found.

Cleaning Gins, Oil Mills, and Seed Warehouses.

In Mexico, where the infestation grows to be very intensive, thousands of live larvæ have been observed to come from the cleaners with the trash. It is the common practice there merely to collect this trash containing the large number of worms and place it in piles. The "cleanings" should be caught in a receptacle rather than allowed to fall on the ground, because the larvæ will crawl and secrete themselves in cracks, crevices, and rubbish of various kinds. This trash should be either burned or subjected to some treatment insuring the death of the insects contained therein. If the trash does not contain too much dirt to make it unburnable, the best plan is to burn it in the boilers. A very good plan was devised by Mr. T. M. Fairbairn for handling the unburnable material. The end was knocked out of an oil barrel and a small steam line run into the barrel, almost to the bottom. The trash from the cleaners fell into the steaming barrel and all larvæ were quickly killed.

After the season is over the gin plant or oil mill should be thoroughly cleaned. All seed and rubbish should be removed from every nook and crevice of the machinery and buildings and burned. If the structure of the buildings permits they should also be fumigated after cleaning.

It is the usual custom to keep enough seed on the plantations for a second planting in case it is necessary. This seed should be as carefully fumigated as the seed that is planted, and as an additional precaution should be stored in a moth-proof screened room. It was very noticeable that the infestation always began earlier in the season and was heavier in the fields nearest the gins and seed warehouses.

Fumigation.

All seed used for planting or kept on the plantation after the first of March should be fumigated. An air-tight room is necessary for a successful fumigation, and it is better to build a special fumigation house at least a hundred yards from the other buildings, so that there will be no danger from fire. Carbon bisulphid is highly inflammable, and no fire should be allowed around the house while fumigation is being done. The ordinary adobe construction is satisfactory, but precautions should be taken to see that plenty of mud is used and all cracks between the adobes well filled. A brick floor set in mortar should be provided and the inside plastered. The plastering not only makes the building more air-tight, but prevents absorption of the gases by the walls. The doors should be of matched wood, and paper should be plastered over the cracks when closed. Seed may be fumigated in sacks or in bulk, but in either case should be packed as little as possible. In no case should the seed to be fumigated be over 5 feet deep. One pound of carbon disulphid should be used for every 80 cubic feet. The entire area of the building should be calculated and not the space occupied by the seed only. As it costs as much to fumigate the air space as it does the seed, it is more economical to make the room only high enough for a person to stand comfortably. The size of the building needed can be calculated from the tons of seed to be fumigated, a ton of seed occupying 85 cubic feet (2½ cubic meters).

All water should be separated from the carbon disulphid and after the seed is in the house the disulphid poured into shallow vessels placed on top of the seed. Not more than a pound should be placed in each vessel, so that it will evaporate quickly. Old gasoline cans cut down to about 3 inches high, or earthenware bowls, make good containers. The vessels should be scattered over the top of the seed pile and the disulphid poured into those farthest from the door first. There is no danger in doing this, but it is more convenient to have a number of half-inch pipes fitted with caps or corks extending through the walls and introduce the disulphid from the outside. As soon as the liquid is poured into the vessels the door should be closed and paper stuck over the cracks with flour paste. The house should be kept closed for at least 24 hours, and longer will do no harm, as continued exposure to the gas does not injure the germination of the seed.

Planting Early Varieties.

From the life history and feeding habits of the pink bollworm it can be readily seen that the later the cotton crop is in maturing the greater will be the amount of loss. Every cultural practice should be used in securing as early maturity as possible of the available cotton varieties.

SUMMARY.

The pink bollworm was introduced into Mexico in 1911 with seed for planting. Five years later it was generally and uniformly distributed throughout the Laguna and had reached its maximum development.

Infestation is started in the spring as soon as squares are formed, by moths emerging from hibernating larvæ, and rapidly increases until practically every boll is infested with several larvæ by fall.

The life cycle is completed in an average of 31 days in the summer, but the larval stage of hibernating or resting larvæ may be extended for 2 years or more.

Dispersal is mainly through the carriage by man of hibernating larvæ in seed, but local dispersion is brought about also by flight and carriage of adults.

The pink bollworm causes approximately 25 per cent gross damage to the Laguna crop by feeding in the bolls and squares. This feeding results in a reduction in the quantity and quality of the lint pro-

duced, reduction in the quantity of seed, and lowering of the quantity and quality of the oil content of the seed.

Early cleaning of fields by burning all the old stalks and bolls, cleaning and fumigation of gins, oil mills, and seed warehouses, the fumigation of all seed kept on the plantations, and the early maturity of the crop are recommended as means of control.

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APPENDIX.

The following generic and specific description is reprinted from "The pink bollworm, *Pectinophora gossypiella*," by August Busck, Journal of Agricultural Research, vol. 9, no. 10, Washington, D. C., June 4, 1917.

HOW TO DISTINGUISH THE PINK BOLLWORM IN THE FIELD.

Definite and final determination of *P. gossypiella* in any stage can be made only by the aid of the microscope; and, unless a collector or inspector is thoroughly familiar with the species, all suspected material should be sent at once to the Bureau of Entomology for determination. Even a fraction of the insect in any of its stages can be recognized under the microscope by the characters given in succeeding sections of this paper.

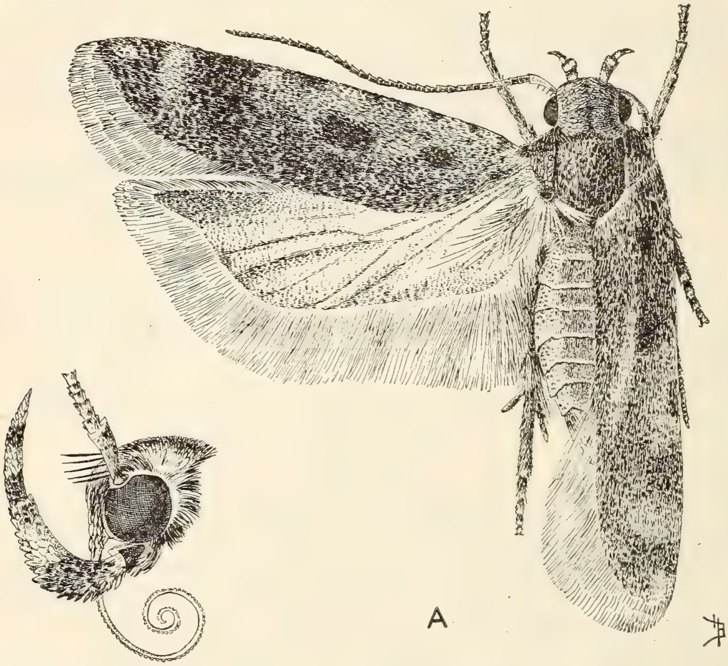


FIG. 4.—Pink bollworm: Adult. (Busck.)

The following essential characters, all of which can be discerned by the aid of a common pocket lens, will enable the practical worker to make a reasonably certain preliminary determination of the insect in all its stages in the field.

If a small dark-brown moth is caught in the cotton field or in a cotton mill or warehouse and is found to have the forewings pointed and the hindwings broad and sinuated below the tip and to possess long curved palpi and long stiff hairs on the first antennal joint, it is reasonably certain that the moth is *P. gossypiella*, the adult of the pink bollworm (fig. 4, *A*).

If, within the cotton boll or associated with stored cottonseed, a small white or pinkish caterpillar with brown head is found and under a hand lens the mandibles are seen to have four teeth (fig. 5, *A–D*) and the crotches on the abdominal prolegs form a partial circle or horsehoe, opening outwards (fig. 5, *H*), the caterpillar will most probably prove to be the pink bollworm.

Again, if, within a cotton boll or otherwise associated with cotton in the field or in the mill, a small lepidopterous pupa is found, which under the lens is found to be entirely covered with a short velvety pubescence and to possess a short, curved, upturned hook at the posterior end (fig. 6, *A–D*), it may with considerable certainty be determined as a pupa of the pink bollworm.

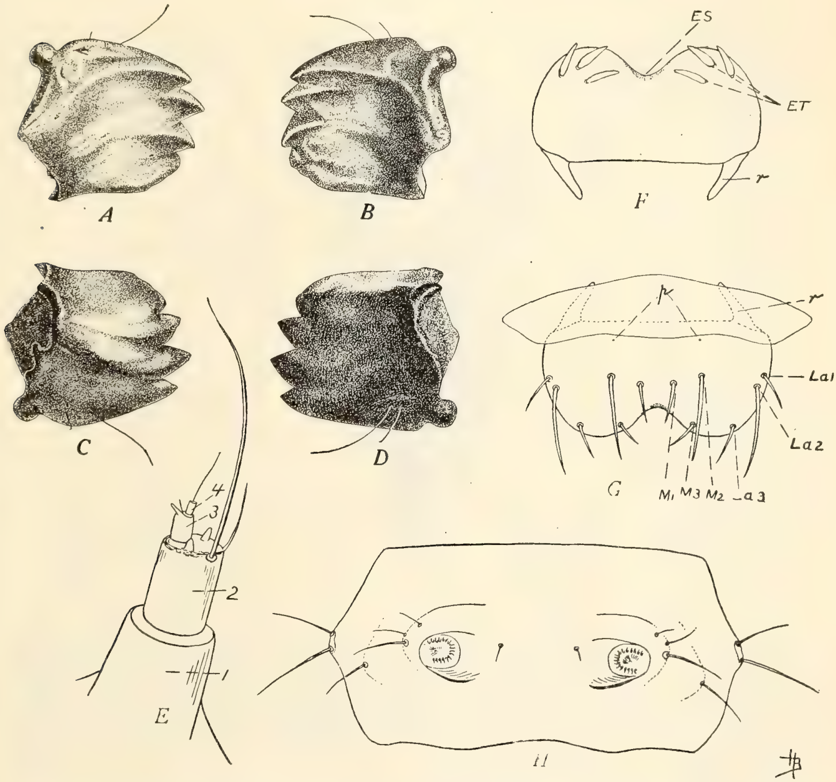


FIG. 5.—Pink bollworm: *A*, Right mandible of larva from underside. *B*, Left mandible from underside. *C*, Right mandible from upper side. *D*, Left mandible from upper side. *E*, Left antenna of larva from underside: *1*, First joint; *2*, second joint; *3*, third joint; *4*, fourth joint. *F*, Epipharynx of larva: *ES*, Epipharyngeal shield; *ET*, epipharyngeal seta; *r*, epipharyngeal rod. *G*, Labrum of larva: La_1, Lateral labral seta 1; La_2, lateral labral seta 2; La_3, lateral labral seta 3; M_1, median labral seta 1; M_2, median labral seta 2; M_3, median labral seta 3; *p*, labral punctures; *r*, epipharyngeal rod. *H*, Underside of third abdominal segment of larva. (Busck.)

GENERIC DESCRIPTION.

Pectinophora, new genus (Gelechiidæ).

Type: *Gelechia gossypiella* Saunders.

MOTH.—Face and head smooth. Labial palpi long, recurved, reaching above vertex; second joint thickened on the underside with slightly furrowed brush, which is evenly attenuated toward apex; terminal joint shorter than second, somewhat thickened with scales in front, compressed, pointed. Maxillary palpi minute, deflected. Tongue long, spiraled, scaled in its entire length. Antennæ serrated and finely ciliated on the underside; basal joint with heavy but sparse (5–6) pecten. Thorax smooth. Forewings (fig. 7, *A*) elongate ovate, pointed, smooth; 12 veins, 7 and 8 stalked to costa, rest separate, 1b furcate at base.[6] Hindwings (fig. 7, *B*) somewhat broader than forewings, trapezoidal; costa deflected from the middle; apex pointed; termen sinuate; 8 veins; 8 connected with cell by an oblique bar; 6 and 7 closely approximate at base; 3 and 4 connate; 5 parallel with 4; frenulum simple in the males, triple in the females. Male genitalia (fig. 9, *B*), with harpes and uncus well developed; tegumen evenly chitinized. Posterior tibiæ (fig. 9, *A*) hairy above.

LARVA.—Head (Pl. V and fig. 8) spherical, nearly circular in outline viewed from above, a little wider than long; greatest width a little behind the middle; incision of dorsal hind margin about one-fourth of the diameter of the head; distance between

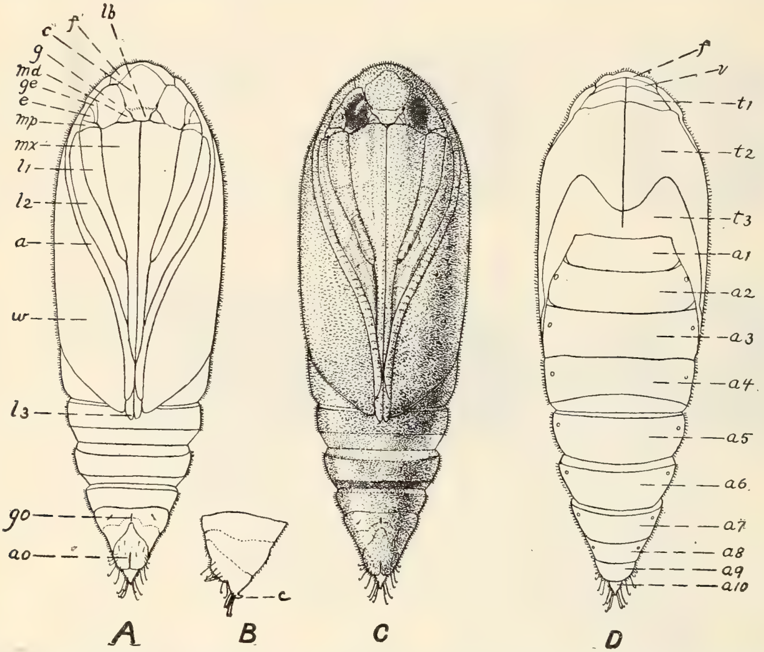


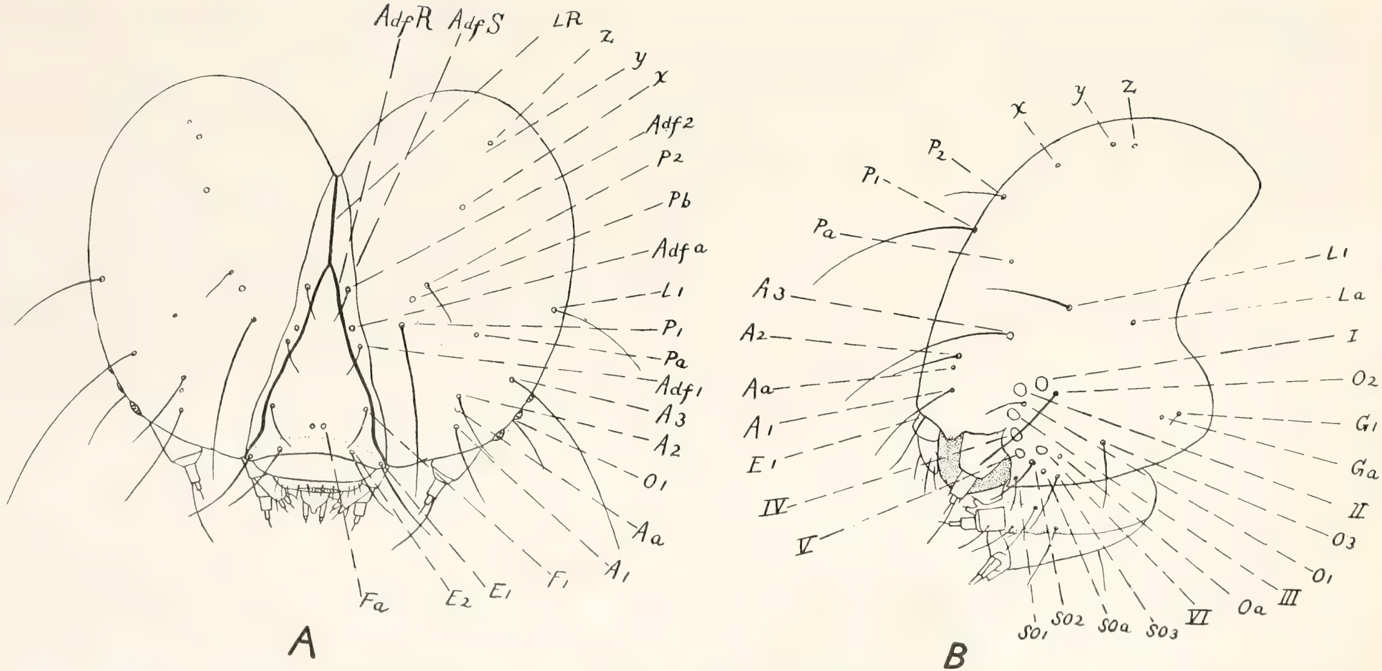
FIG. 6.—Pink bollworm. *A*, Pupa from front: *lb*, Labrum; *f*, front; *c*, clypeus; *g*, gena; *md*, mandibles; *ge*, glaced eye; *e*, eye; *mp*, maxillary palpus; *mx*, maxilla; l_1, first thoracic leg; l_2, second thoracic leg; l_3, third thoracic leg; *a*, antenna; *w*, forewing; *go*, genital opening; *ao*, anal opening. *B*, Tip of pupa from left side: *c*, Cremaster. *C*, Mature pupa, with eyes of the imago visible through pupal skin. *D*, Pupa from back: *f*, Front; *v*, vertex; t_1, first thoracic segment; t_2, second thoracic segment; t_3, third thoracic segment: a_1, first abdominal segment; a_2, second abdominal segment; a_3, third abdominal segment; a_4, fourth abdominal segment; a_5, fifth abdominal segment; a_6, sixth abdominal segment; a_7, seventh abdominal segment; a_8, eighth abdominal segment; a_9, ninth abdominal segment; a_{10}, tenth abdominal segment. (Busck.)

dorsal extremities of hind margin about one-half of the width of the head. Front triangular, reaching beyond the middle; adfrontal sutures somewhat undulating, reaching to the incision of hind margin; adfrontal ridges converging from near the middle, at the point of attachment of tentorial arms, to the longitudinal ridge, which is one-half as long as front. Projection of the dorsal margin over the ventral is one-half of the diameter of the head. Triangular plates of hypostoma distinctly separated by a slightly pigmented gula, nearly equilateral, but somewhat elongated and projecting slightly beyond the ventral margin of epicranium.

Ocelli six; i, ii, v, and vi forming a parallelogram; iii and iv on a line between ii and v; v smaller than the rest.[7] Epistoma with the usual two pairs of setæ (E_1, E_2) well developed.

[6] The European (*Gelechia*) *Pectinophora malvella* Zeller exhibits an amount of variation of the venation in the forewing which is very unusual in this group of insects. Veins 2 and 3 in this species are sometimes coincident or partly coincident at base or at tip; the variations sometimes differing in the two wings of the same insect. No such variation has been ascertained in *P. gossypiella*, where the venation seems constant, as given above.

[7] This numbering of the eyes differs from that of Fracker in that his numbers 5 and 6 are reversed, so as to make them continuous with the rest. (Fracker, S. B. The Classification of Lepidopterous Larvæ . . . 169 p., 10 pl. Urbana, Ill., 1915. Bibliography, p. 145–146. Illinois Biological Monographs, v. 2, no. 1.)



A, Head capsule of larva from front. *B*, Head capsule of larva from side. *AdfR*, adfrontal ridge; *AdfS*, adfrontal suture; *LR*, longitudinal ridge; E_1, epistomal seta 1; E_2, epistomal seta 2; *Fa*, frontal puncture; F_1, frontal seta; Adf_1, adfrontal seta 1; Adf_2, adfrontal seta 2; *Adfa*, adfrontal puncture; A_1, anterior seta 1; A_2, anterior seta 2; A_3, anterior seta 3; *Aa*, anterior puncture; P_1, posterior seta 1; P_2, posterior seta 2; *Pa*, posterior puncture a; *Pb*, posterior puncture b; *x*, *y*, and *z*, ultraposterior punctures; L_1, lateral seta; *La*, lateral puncture; *I*, ocellus i; *II*, ocellus ii; *III*, ocellus iii; *IV*, ocellus iv; *V*, ocellus v; *VI*, ocellus vi; O_1, ocellar seta 1; O_2, ocellar seta 2; O_3, ocellar seta 3; *Oa*, ocellar puncture; SO_1, subocellar seta 1; SO_2, subocellar seta 2; SO_3, subocellar seta 3; *SOa*, subocellar puncture; G_1, genal seta; *Ga*, genal puncture. (Busck.)

PINK BOLLWORM.

Frontal punctures (Fa) close together, anterior to frontal setæ (F_1); distance between punctures less than distance between puncture (Fa) and setæ (F_1); frontal setæ (F_1) and adfrontal setæ (Adf_1 and Adf_2) nearly equidistant; second adfrontal seta (Adf_2) approximate to but before beginning of longitudinal ridge (LR); adfrontal puncture (Adfa) midway between adfrontal setæ.

Epicranium with normal number of primary setæ, 13, and punctures, 7, and with three small ultraposterior punctures [8] (x, y, and z).[9]

Anterior setæ [10] (A_1, A_2, A_3) in a slightly obtuse angle; A_1 and A_2 closer together than A_2 and A_3; anterior puncture (Aa) between A_1 and A_2. Posterior setæ [11] (P_1, P_2) and posterior punctures (Pa, Pb) near the middle of the head; P_1 on the level with

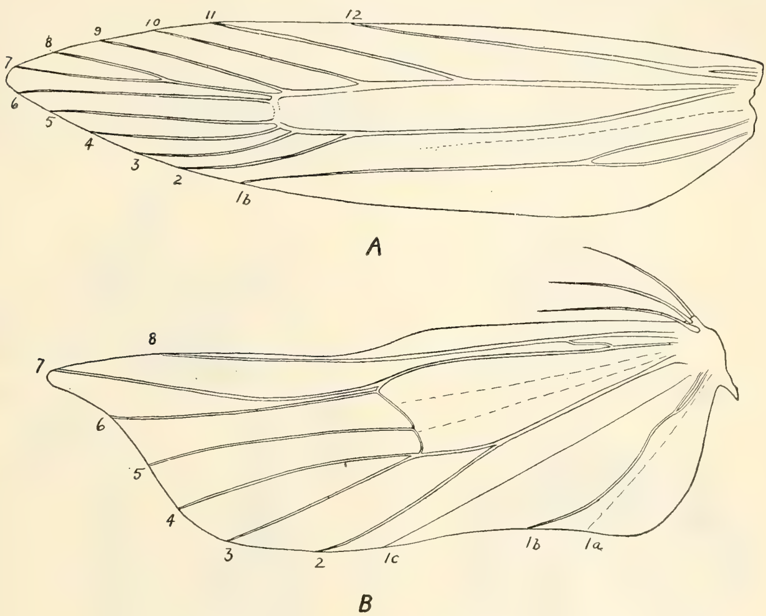


FIG. 7.—Pink bollworm: *A*, Venation of forewing; *B*, venation of hindwing. (Busck.)

adfrontal puncture [12]; P_2 posterior to Adf_2. Pa equidistant from P_1, A_3 and the lateral seta (L_1) remote from the anterior group, nearly on the level with P_1; lateral seta (L_1) remote from A_3, nearly on the level of Pb; lateral puncture (La) posteroventral to the seta, remote. Of the ocellar setæ (O_1, O_2, O_3),[13] O_1 is equidistant from and lateral to ocelli ii and iii, O_2 is closely approximate and posteroventral to ocellus i; O_3 is directly ventral and remote from O_2, on a line with ocelli v and vi; ocellar puncture (Oa) between O_3 and ocellus vi, approximate to latter. Subocellar setæ (So_1, So_2, So_3) triangularly placed, nearly equidistant; subocellar puncture (Soa) between and equidistant from So_2 and So_3. Genal seta (G_1) and puncture (Ga) both present; puncture anterior to seta.

Labrum (fig. 5, *F*, *G*) with median incision rather deep and evenly rounded. The three lateral setæ (La_1, La_2, La_3) close to edge, La_1 and La_2 closely approximate, La_3 remote; median setæ (M_1, M_2, M_3) in the usual Micro arrangement with M_2 lateral and slightly posterior to M_1; M_3 close to anterior margin on a line with La_3; M_1 and M_2 on a line respectively with La_2 and La_1.

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[8] The nomenclature of the head setæ has been adopted from Heinrich [Heinrich, Carl. On the taxonomic value of some larval characters in the Lepidoptera. *In* Proc. Ent. Soc. Wash., v. 18, no. 3, p. 154–164, illus. 1916.] with certain minor modifications, noted in the following footnotes and concurred in by Mr. Heinrich.

[9] So-called "secondary punctures" of Heinrich, sometimes bearing minute setæ.

[10] Anterodorsal setæ of Heinrich.

[11] Posterodorsal setæ of Heinrich.

[12] The term "on the level with" is used in these descriptions as the head setæ are seen in frontal projection (Pl. V, *A*); anything above a level is termed "posterior" and anything below is termed "anterior."

[13] Heinrich's numbering reversed.

Epipharyngeal shield (ES) merely a slight chitinization of the edge of the median incision; epipharyngeal setæ narrow plates, triangularly grouped near anterior margin. Epipharyngeal rods not discernible in the labrum proper, only represented by their posterior projections, which are rather well developed.

Mandibles (fig. 5, *A–D*) strong, as broad as long, with four stout, rather short teeth: the three lower ones pointed; the upper blunt; a fifth lower tooth is slightly indicated on the underside; one long and one shorter seta on upper side near lower edge.

Labium and maxillæ normal (fig. 8, *C*).

Antennæ (fig. 5, *E*) four-jointed, with second joint considerably longer than joint 3, longer than broad; the longer seta longer than the entire antenna; papillæ minute, much shorter than third joint.

Three pairs of normal thoracic feet; four pairs of abdominal prolegs with crotches of uniform size in an incomplete circle, opening outwardly (fig. 5, *H*); anal prolegs with a transverse row of uniordinal hooks.

The arrangement of the body setæ is normal, as shown in figure 10, *A*, *B*. It differs from that of Gelechia in having the three setæ on prespiracular plate of prothorax nearly equidistant, while in Gelechia the posterior seta is farther separated from the two others than they are from each other, and in having the three setæ vii of the proleg-bearing abdominal segments arranged in a triangle, not in a line as in Gelechia.

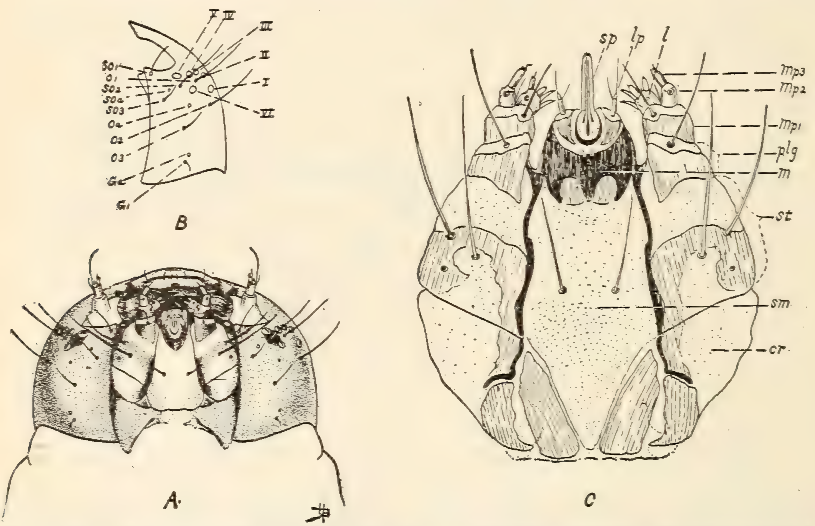

FIG. 8.—Pink bollworm. A, larval head from underside. B, Seta arrangement of epicranium in figure A: *I*, Ocellus i; *II*, ocellus ii; *III*, ocellus iii; *IV*, ocellus iv; *V*, ocellus v; *VI*, ocellus vi; O_1, ocellar seta 1; O_2, ocellar seta 2; O_3, ocellar seta 3; *Oa*, ocellar puncture; SO_1, subocellar seta 1; SO_2, subocellar seta 2; SO_3, subocellar seta 3; *SOa*, subocellar puncture; G_1, genal seta; *Ga*, genal puncture. C, Labium and maxillæ: *sp*, Spinneret; *lp*, labial palpus; *l*, lacinia and galea; *m*, mentum; *sm*, submentum; *cr*, cardo; *st*, stripes; *plg*, palpiger; mp_1, maxillary palpus, first joint; mp_2, maxillary palpus, second joint; mp_3, maxillary palpus, third joint. (Busck.)

The genus differs further from Gelechia in the possession of an antennal pecten in the moth, and in the arrangement of the setæ of the larval head; Aa is anterior to A_2, not posterior to it as in Gelechia; P_1 and P_2 are posterior, respectively, to Adf_1 and Adf_2, which in Gelechia are nearly opposite to these, and L_1 is posterior to P_1, not on the level with it as in Gelechia.

The most striking larval difference is in the crotches of the abdominal prolegs, which are uniordinal and arranged in an incomplete circle, broken outwardly (fig. 5, *K*). In Gelechia they are biordinal and in a complete circle.

PUPA.—The pupa of *Pectinophora gossypiella* is pubescent, without any long setæ except on last joint, and thus is easily distinguished from the smooth, seta-bearing pupa of Gelechia; cremaster present.

SPECIFIC DESCRIPTION.

MOTH (fig. 4, *A*).—Labial palpi reddish brown; second joint with two diffused black bars exteriorly; terminal joint with two well-defined, broad, black annulations, one at base, the other at apical fourth. Antennæ brown with narrow black annulations;

basal joint with long black pecten. Face and head light reddish brown with some pale iridescent scales. Thorax reddish brown with a sprinkling of black around the collar; patagia somewhat lighter brown, unmottled. Forewings darker brown with a series of small, ill-defined, black spots along the costal edge from base to apical fourth, where there is a larger dash of light ocherous brown; dorsal edge and apical part of wing suffused with darker, blackish brown; the middle of the wing is irregularly sprinkled with blackish scales and contains on the cell an ill-defined, round, blackish spot, sometimes divided into an upper and lower spot; there is also a smaller spot on the base of the cell; the pattern of the wing is rather vague and there is considerable variation in different specimens; in many there is an ill-defined blackish fascia at apical fourth just before the light costal dash, but in other specimens this fascia is not present and the round dorsal spot is dissolved into several smaller spots. Cilia

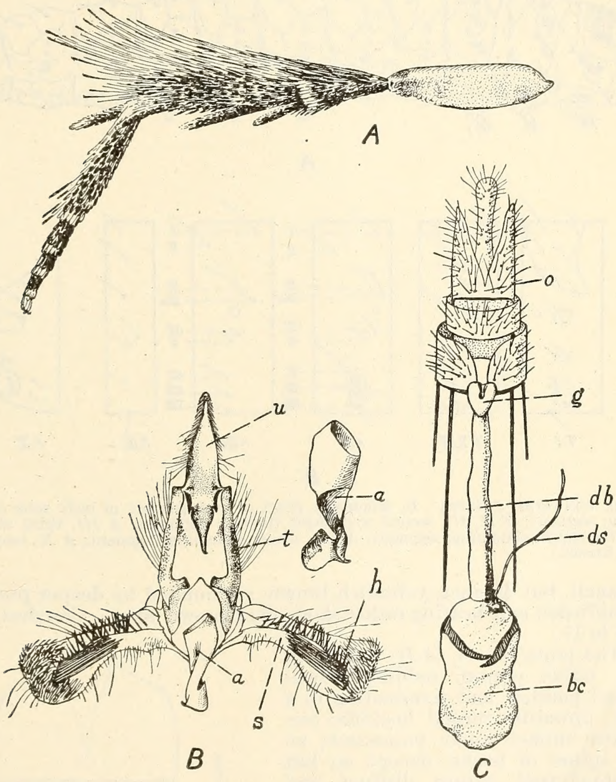

FIG. 9.—Pink bollworm: *A*, right hind leg. *B*, genitalia of male: *u*, Uncus; *t*, tegumen; *h*, harp; *a*, ædœagus; *s*, sacculus. *C*, genitalia of female: *o*, Ovipositor; *g*, genital plate with genital opening; *db*, ductus bursæ; *ds*, ductus seminalis; *bc*, bursa copulatrix. (Busck.)

light ocherous brown, streaked with blackish. Hindwings dark fuscous, somewhat iridescent, lightest toward base; cilia ocherous, terminal and apical parts suffused with dark fuscous: vein 1c with long, ocherous fuscous hairs on the upper side. Abdomen flattened and ocherous above, dark brown laterally with underside suffused with black and with ocherous scaling at the joints. Legs (fig. 9, *A*) blackish fuscous with narrow ocherous annulations at the joints. The abdomen is very similarly shaped in the male and in the female and it is exceedingly difficult to distinguish the sexes, even in living moths, without dissection or by examination of the frenulum. The male genitalia (fig. 9, *B*) are remarkably small in proportion to the size of the species: harpes narrow at base, broadening towards tip; tip strongly haired; a cluster of long, heavy, straight spines from inner side, well within the tip; sacculus armed on its edge with a row of stout spines; uncus moderately long, broad at base, tapering to a point, laterally heavily haired; ædœagus short, stout, with a terminal hook. In the female the ovipositor is weakly chitinized, covered with stiff hairs;

genital plate heart shaped; bursa copulatrix with two opposite, strongly chitinized, hornlike, serrated invaginations (fig. 9, *C*).

Alar expanse 15 to 20 mm.

Full-grown larva.—The full-grown larva (fig. 10, *A*) is 11 to 13 mm. long, cylindrical, white, with dorsal side strongly suffused with pink. Head reddish brown with blackish brown mandibles and the other trophi yellowish. Thoracic shield rather small, divided in the middle, dark brown. [On each side of the thoracic shield is a small, slightly depressed, kidney-shaped spot, thinly chitinized and less pigmented than the rest of the shield. This purely specific character is easy to observe and may be of some assistance as contributory evidence in a preliminary determination of the pink bollworm in the field (fig. 11).] Anal plate small, dark brown.

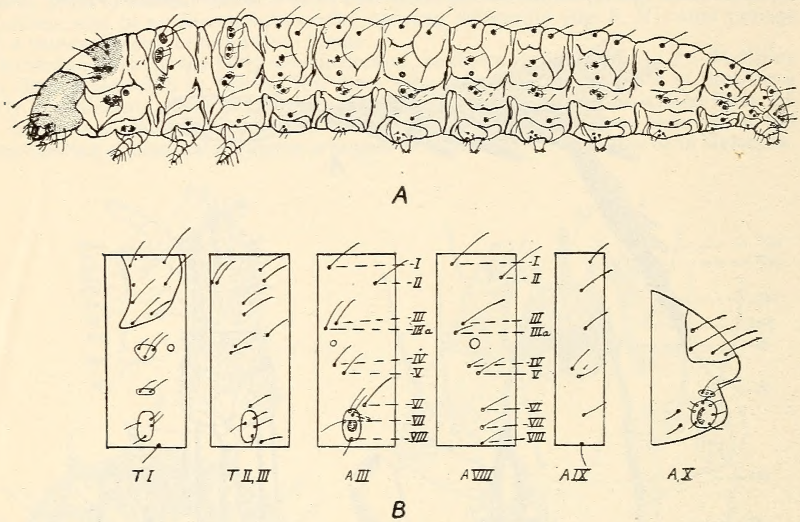

Fig. 10.—Pink bollworm: *A*, larva. *B*, schematic chart of arrangement of body setæ of larva. *T I*, first thoracic segment; *T II, III*, second and third thoracic segments; *A III*, third abdominal segment; *A VIII*, eighth abdominal segment; *A IX*, ninth abdominal segment; *A X*, tenth abdominal segment. (Busck.)

Tubercles small, but distinct, yellowish brown, surrounded by deeper pink than the prevalent suffusion and bearing rather short, dark-brown setæ. Crotches of abdominal feet 15 to 17.

Pupa.—The pupa (fig. 6, *A-D*) is 8 to 10 mm. long, rather plump, reddish brown; posterior end pointed and terminating in a short, stout, upwardly turned hooklike cremaster; entire surface finely pubescent; no long setæ, spines or hooks, except on last joint; fronto-clypeal suture distinct and curved sharply upward; clypeus, labrum, pupal eyes and mandibles distinctly indicated; antennæ diverging at their extreme tip and not reaching to the tips of the wings; metathoracic legs reaching slightly beyond the wings to fifth abdominal segment. Spiracles small, normal. Anal opening large, slitlike, surrounded by strong hooked setæ, 5 or 6 on each side; cremaster surrounded with 6 to 8 similar, strong, hooked setæ. Genital opening slitlike, single in both sexes. When mature, the pupa becomes much darker (fig. 6, *C*); the imago's eyes can be seen prominently under the gena of the pupal skin, and the segmentation of the adult antennæ and legs becomes discernible.

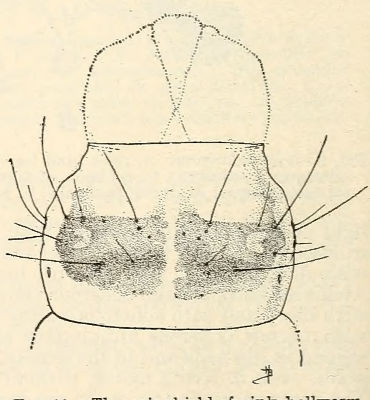

Fig. 11.—Thoracic shield of pink bollworm larva. (Original.)