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LIFE HISTORY AND HABITS OF THE THURBERIA BOLLWORM, *Thurberiphaga diffusa* BARNES (*Noctuid*)

By C. T. Vorhies

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*In coöperation with United States Department of Agriculture, Bureau of Plant Industry.

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LIFE HISTORY AND HABITS OF THE THURBERIA BOLLWORM, *Thurberiphaga diffusa* BARNES (*Noctuid*)

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INTRODUCTION AND HISTORICAL SKETCH

Late in the year 1912 a variety of cotton boll weevil* was found breeding in the plant known as wild cotton (*Thurberia thespesioides* A. Gray) in the mountains of southern Arizona. Announcement of this discovery early in 1913 by Cook (5) aroused interest in other insects for which this plant might be the host, because of the possibilities of infestations with new pests which might result from growing cultivated cotton in valleys contiguous to the wild plants. *Thurberia*, while a small-fruited plant, (Fig. 1) bearing on its seeds only short and scanty fiber, is nevertheless more closely related to *Gossypium* than any other genus of malvaceous plant. While at first sight it may not appear to any but a botanist to have close resemblances to cotton, a little familiarity with both plants soon discloses many striking similarities. The general infestation of *Thurberia* with a weevil closely resembling the all-too-well-known Mexican boll weevil, leads naturally to the inference that the insect pests of the one plant might readily become pests of the other. This conception was greatly strengthened in 1915 when Coad (3) showed that the Thurberia weevils would readily attack domestic cotton if favorable opportunity offered. It is further strengthened by the fact that another insect, a small moth† probably native to the wild cotton, (12) has become so widely distributed and well known as a cotton insect in Arizona and southern California that its real origin is almost lost sight of. This insect is well known as the "cotton leaf perforator" (11) and is common throughout the cotton-growing regions above mentioned. Fortunately, because of its small size and the nature of its work, it ordinarily does no appreciable damage. In the season of 1924, however, it was reported to have been distinctly injurious in the Imperial Valley and Yuma districts.

**Anthonomous grandis thurberiae* Pierce.

†*Bucculatrix thurberiella* Busck

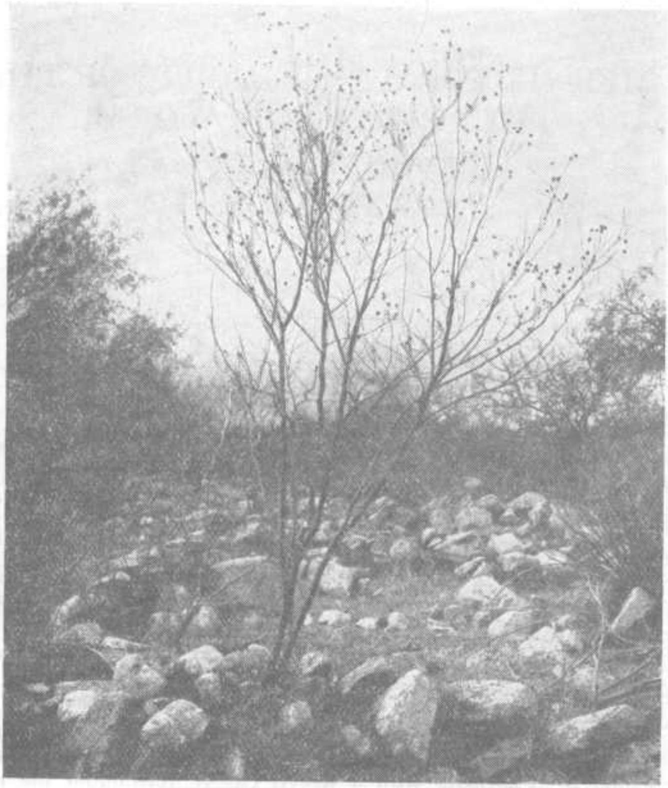

Fig. 1.—A specimen of *Thurberia* in winter condition, showing the numerous small bolls. This crop of bolls is rather less than average.

Pierce and Morrill in 1914 (12) made a study of the insects taken on *Thurberia*, as a result of which they listed 83 species thus found. These they classed as "injurious 25, nectar visiting 40, parasitic 12, and predacious 6, in their purposes of visiting the plant." In their publication is noted for the first time the bollworm which is the subject of the present investigation, the moth not having been connected up with the larval stages until some years later. The authors begin their account of the worm with the following significant statement (p. 17): "The Thurberia boll worm is considered the most destructive of all the insects attacking Arizona wild cotton." Also (pp. 18-19), "The Thurberia boll worms appear to feed upon Egyptian cotton as readily as upon the wild cotton." Morrill, in personal conversations with the author of this bulletin has also urged the advisability of investigating the possibilities of transfer of this insect to cultivated cotton.

In view of these evident possibilities, it was decided in 1920 to undertake an investigation of the details of the life history and habits of this insect, as well as to seek facts bearing upon its possible adaptability to cotton under cultivation.*

In the autumn of 1918, Dr. C. H. T. Townsend of the United States Department of Agriculture, spent several weeks in camp in Sabino Canyon in the Santa Catalina Mountains making observations on the Thurberia bollworm. A manuscript report of his work (14) was made available to the present author by the late Dr. W. D. Hunter of the Federal Horticulture Board. This report was valuable in the present investigation as a point of departure, affording dates of activity and other data from which to work. Townsend succeeded in carrying a number of these bollworms through to pupation. These pupae, 22 in number, were then sent to Washington, and later transferred to Louisiana and Texas points for overwintering. From these there issued at Brownsville and Victoria, Texas, August 2 to September 1, 1919, a total of nine specimens, three of which were damaged by careless handling.† Five of these, three males and two females, were cotypes for the description of "A New Noctuid from Arizona" by H. G. Dyar (6). Dyar described this not only as a new species but as a new genus under the name *Thurberiphaga catalina, (Lepidoptera, Noctuidae).*

It has since been determined that this species was first described by Barnes as *Alaria diffusa*, (2) only the moths being known to him. Dyar's new genus is now recognized as valid, but *catalina* sinks as a synonym, and the correct scientific name becomes *Thurberiphaga diffusa* Barnes (7). Mr. Foster H. Benjamin has kindly compared our specimens with the types of *diffusa* in the Barnes collection.

DESCRIPTIONS

THE MOTH

Barnes' description (2) of the imago (Fig. 2a) follows:

"*Alaria diffusa*, n. sp. —♀ expanse: 35 mm. Head and palpi pink, antennae yellowish-brown, collar flushed with pink at base, yellow above. Thorax pale yellow, abdomen a little darker, more dusky-yellow than thorax. Primaries clear pale yellow, showing, however,

*Moreland, after our investigations were begun, reported (10) "The Thurberia boll worm seems to be far more destructive than the Thurberia weevil. The worm infestation in 1921 was much heavier than that of the weevil and judging from the worm sign in the 1920 crop of bolls the worm damage was also greater than the weevil the previous year. In some places fully one-fourth of the 1920 crop of bolls had been eaten out by the worms."

†Webb, (15) reporting Townsend's findings, records the emergence of a tenth individual at Brownsville on August 28, 1920.

under the lens a slight dusting with orange scales between the veins, barely discernible to the naked eye in some places as faint longitudinal streaks. The pink markings are arranged as follows: From middle of, but not quite reaching costa there is a well-marked blotch, quite well defined, which runs downward and outward across cell, here it makes a well-marked angle and is continued to middle of inner margin as a somewhat narrower band, parallel to outer margin. This median band is connected with a marginal band by a broad shade in the middle of the wing, which is sharply defined above, but gradually fades into the yellow below. The marginal band leaves the external margin just below apex, and is narrow and sharply defined above the connecting shade, below it is not so sharply limited, and fades out as it reaches the inner angle.

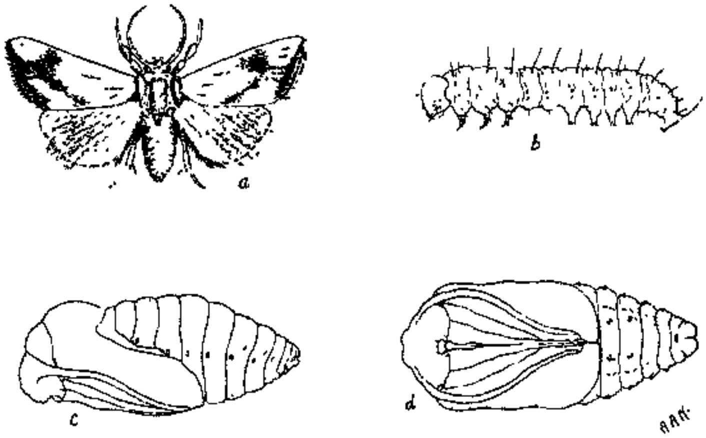

Fig. 2.—(a). Adult *Thalerophaga diffusa*, about life size,
(b). Newly hatched larva, x 21,
(c) Pupa, x 3½,
(d). Pupa, x 3½.

These bands divide the wing into three areas, a basal to the median shade, one above outer half of inner margin, and one below outer half of costa. The first two are not so sharply defined on the borders which are formed by the pink bands, as these are here more diffuse and shade into the yellow, the last, however, is clear cut at its outer and lower sides. The outer edge of the marginal band is regularly toothed, the points just reaching the basal fringe line. The filling between the teeth is yellowish, dusted with pink. The fringe is pink outwardly, somewhat lighter yellowish internally, basal line pink, not very distinct. Secondaries pale yellowish, quite thickly dusted with pink over outer half of wing, forming a broad pinkish band from costa, fading out shortly beyond middle of wing. Fringe concolorous.

"Beneath primaries quite thickly dusted with pink, except along inner margin and a subapical patch, which are yellow. Secondaries have a pink blotch at middle of costa, from which a faint, broad and diffuse mesial band runs partly across wing, disappearing about the middle.

"Type: 2 ♀'s, Arizona, Huachuca Mts., August; Santa Catalina Mts., August 24-30. The latter specimen from Mr. Poling."

This is a very beautiful moth for a Noctuid. Its colors are practically identical with the colors of the withering flowers of *Thurberia* (pink and white), so much as to suggest at once a protective resemblance, but, unfortunately for this conception, we have never found the moth resting in or on any stage of the flower. The freshly opened blossom is pure white.

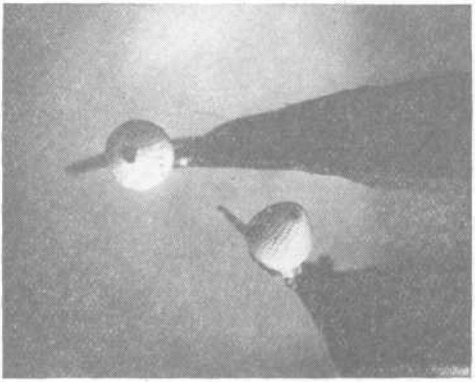

Fig. 3.—Eggs of *Thurberiphaga diffusa* on tips of Thurberia leaves, x 11.

Detailed studies of the life history of *Thurberiphaga diffusa* were begun in 1920, but, owing to lack of knowledge of the insect and its habits, little was learned of the early stages in that season. These studies were continued in 1921, 1922, 1923, and 1924, as a result of which the details are now well understood.

THE EGG

The dates and characteristic manner of oviposition will be described in connection with the fruiting habit of the plant. The egg (Fig. 3) of this moth was well described by Pierce and Morrill (12) as follows:

"The egg is pure white in color, truncate-conical in form, with crater-like apical depression. Greatest diameter 0.79 to 0.83 mm.; height, 0.79 to 0.8 mm.; diameter of entrance to apical cavity, 0.13 mm.; edges jagged. Surface of eggs marked with slightly depressed reticulations forming polygonal cells, small at base of the eggs and gradually increasing in size as the diameter of the egg decreases. About 52 cells occur around largest circumference and about 21 cells around smallest circumference. As the embryo develops the egg gradually becomes distinctly pinkish."

The present author would add to this only the observation that the fresh eggs usually show a greenish tinge through the white shell and later become distinctly pink as described.

THE LARVA

The newly hatched larva is from 1.3 to 1.5 mm. in length, stretching to 2 mm. when crawling (Fig. 2b). It is straw to orange-yellow in color, with brown head, and is relatively more hairy than the last instars. The second instar larva is fairly dark red in color, while the third and fourth instars are especially so. Pink is not at all a proper designation for the color in these stages. The usual color is near ox-blood red (13). Heads are light to darker brown, depending upon whether early or late in the instar. The larva in the last instar reaches a length of 23-24 mm., stretching to 25-26 mm., with a width of 5 mm. It is relatively smooth, with light brown head and prothoracic shield, and also a light brown anal shield. The body is light green in ground color, with more or less of a reddish blush over the green. Distinct red blotches bound the black spiracles, giving the effect of an interrupted lateral band of pink or reddish. The dorsal vessel, carrying greenish blood, is distinctly visible.

THE PUPA

"The pupa is robust, measuring about 10 mm. in length, and 5 mm. in width. It is light brown in color with dark brown spiracles." Pierce and Morrill (12). (Fig. 2c, d).

The above description can hardly be improved upon for brevity. The pupa lies in a cell formed in the soil by construction of a rather dense and resistant cocoon, about 15 mm. in length. The writer, as well as Moreland (10), has conducted diligent search under Thurberia plants to a depth of 3 to 4 inches in attempts to find the pupal cocoons in nature, but without success. In pots or jars in the laboratory the cells are formed at a depth of 1.5 to 2 inches, but the depth may well be greater in the open, and the larvae may wander to considerable distances from the plants before entering the soil.

NATURAL ENEMIES

While a few Braconid parasites were reared from bollworms collected in the field in the earlier years of the investigation, the later phases of the work dealt increasingly with larvae hatched indoors or under screen, far removed from the normal habitat of *Thurberia*, and hence free from parasites. As the work proceeded it seemed more and more evident that the bollworm was not potentially dangerous to cotton. For these reasons no organized effort was made to study the parasites, and no further details from our own work will be offered. Townsend recorded a parasitism of 29 percent of the larvae, four species of hymenopterous parasites having been reared by him. His results have been published by Webb (15), and are readily available to those interested.

No egg parasites have been discovered. Occasionally eggs were found which appeared to have been robbed of their contents by some sucking insect. While we have sometimes found hollowed-out Thurberia bolls torn open, presumably by birds, we have not observed so large a percentage thus attacked as was mentioned by Townsend, who reported in one case about 5 percent, and in another 10 percent of infested bolls destroyed by birds, probably Arizona Jays.

DISTRIBUTION OF PLANT AND BOLLWORM

All data concerning the distribution of the host plant *(Thurberia thespesioides)* of this insect as known up to 1922 have been brought together and summarized by Hanson (8). His publication includes a distribution map compiled from these data. To the information thus published we can add for the purpose of this report two important items. On the eastern bahada of the Sierrita Mountains, *Thurberia* occurs abundantly in a number of washes which empty into the Santa Cruz River about opposite Continental. The plant has also been found in the Tortillita Mountains since the publication of Hanson's bulletin. It will not be necessary to discuss further in this publication the distribution of the host plant, but a map showing the known distribution of the bollworm is presented (Fig. 4). In addition to the author's personal observations on the occurrence of bollworm infestations on *Thurberia*, all available records of collections of the moths have been compiled and mapped. As will be seen later from the account of the habits of the insect the capture of moths in a given locality is fairly conclusive evidence of occurrence of larvae in *Thurberia* not very far distant.

CORRELATION IN ACTIVITY OF PLANT AND BOLLWORM

FRUITING PERIOD OF *THURBERIA*

As there exists a close correlation between the seasonal activity of the insect and its host plant, some discussion of the normal growth and fruiting habit of the latter is necessary. *Thurberia* is a deciduous, perennial shrub, occasionally attaining almost the stature of a tree. Its habitat

Fig. 4.—Map of the southern part of Arizona showing the present known distribution of the Thurberia bollworm in the mountain ranges. Thurberia plants occur in many places which have not been checked for bollworm infestations.

Key to the names of mountains indicated by number on the map:

1. Chiricahua Mts.
2. Dos Cabezas Mts.
3. Pinalino Mts.
4. Galiuro Mts.
5. Dragoon Mts.
6. Mule Mts.
7. Huachuca Mts.
8. Patagonia Mts.
9. Whetstone Mts.
10. Santa Rita Mts.
11. Rincon Mts.
12. Tanque Verde Mts.
13. Santa Catalina Mts.
14. Tortilla Mts.
15. Tortillita Mts.
16. Picacho Mts.
17. Tucson Mts.
18. Sierrita Mts.
19. Tumacacori Mts.
20. Baboquivari Mts.
21. Coyote Mts.
22. Roskruge Mts.
23. Maricopa Mts.
24. Superstition Mts.

in the mountain canyons is in the main well described by Coad (3), (4), Hanson (8), and Bailey (1), though the present author would emphasize the fact that at the higher elevations it is much less confined to the stream-beds, and much more promiscuously scattered over the mountain sides, while at lower levels, 2,200-4,000 feet, and outside the canyons proper, it is practically confined to the sand washes. This wider distribution in the higher and rougher parts of its range is most important to recognize in any discussion of the possibility of eliminating its insect pests, as, for example, through eradication of the plant. Another point of importance is the fact that its normal flowering and fruiting period is in the autumn. The present author during several successive years of observation has been generally unable to find plants in bloom or fruiting before late August, or evidence, in the form of new fruits of the year, that blooms were formed in the spring. At a little higher altitude in the canyons not even leaves appear on the plants until May. The normal blooming period begins in the latter half of August, first blooms appearing in a notable number of instances on or very near to August 25. This brings the fruiting period into September. It may be added that once the autumn blossoming and fruiting has begun, a great profusion of buds, flowers, and fruits develops rapidly, when moisture conditions are at all good. Fruiting continues into October. We believe that the above represents what may legitimately be called a normal blooming and fruiting period of *Thurberia*, though there occur occasionally some notable exceptions. Coad (3) (4) as a result of his observations made in the season of 1914 described in considerable detail what he conceived to be the seasonal activity of *Thurberia*, beginning with heavy squaring by May 1, and blooming about May 7 at the lower altitudes, then a progressively later beginning as higher and higher altitudes were reached, plants above 5,000 feet not starting to square until August. The plants noted at the low altitudes, moreover, produced in 1914 a series of crops amounting in a few cases to four, and in many cases to three. Coad says, however, (4): "Regardless of the previous activity of the plants, the last crop of fruit (produced during August and September) is always the largest and blooming extends over a longer period of time. Most of the plants stopped blooming during the latter part of September, though quite a few continued blooming into early October." The quoted statement agrees with our observations of several years. Unfortunately for the general conclusions which it was natural for Coad to draw from his observations, 1914 could hardly have been a normal season. During 5 or 6 years prior to the 1924 season, only once has exception to the autumn fruiting period been noted. This exception was in line with Coad's observations in 1914, but only a single small spring crop of bolls was noted. The year 1924 was exceptionally dry in southern Arizona in the summer months, and a bewildering variety of exceptions to the usual fruiting activity was observed. Many plants perished from the drought. Other groups more favorably situated bloomed with a greater or less degree of normality, but at different times. A group of plants in one location might be found blooming freely by mid-August, while another not many miles away, or even not many rods away, might not bloom until the normal late-August period. Moreover, as we went from place to place on this and Thurberia weevil work we noted many individual plants and sometimes small groups of plants which had borne some fruit in the early season. Fruits of the year, though ripe and dehiscent, may be readily distinguished by their gray-green color from the old, brown, weathered bolls of the previous year. Also in a few instances, green bolls in mid-August indicated a late-July or early-August blooming. At the same time (late August) notably in Sabino Canyon, individually fortunate plants were in full bloom, though with drooping foliage, while the majority had very few or no blossoms, and many others were quite dead. Coad further says (4): "The active period of the plant will probably vary with the different years according to climatic conditions. The winter of 1913-14 was exceptionally mild and consequently some of the lower plants may have started blooming earlier this season than is usual."

While agreeing in general with the above statements the present author is inclined, on the basis of the observations of several years previously mentioned, to believe that the active blooming period varies less than Coad had cause to assume, and that there is at least an equal chance that a deficiency in moisture during the winter of 1913-14 was a co-factor, if not the chief one, causing the abnormal blooming of 1914. Examination of the records of the United States Weather Bureau shows a supranormal mean temperature for each of the first 5 months of 1914, amounting to a total of $+11.4°$ departure from normal. Precipitation records for the same 5 months show deficiencies for January and February amounting to 1.04 inches, a smaller surplus in March of .45 inch, a deficiency for April of .31 inch which, however, was a 100 percent deficiency, there being no rain in that month. In May there was .49 inch of rainfall, a .38 inch departure from normal but it is unlikely that this affected the blooming since it occurred in the first week of May. Whether a 33 percent deficiency in rainfall or a monthly surplus of approximately three degrees in mean temperature is of the greater importance we are not prepared to say. Aside, however, from the fact already mentioned that in 1924, an extremely dry year, we found the greatest number of exceptions to the rule, we found that with an abundance of water, *Thurberia* growing in the introduction gardens on the University Campus showed no exception. Here, at an elevation even less than the lowest at which plants were studied by Coad, the luxuriantly growing plants have only once been observed by the writer to put forth a single blossom prior to late August, generally the first being noted very near to August 25. There is no lack of either heat or moisture here, since the altitude is but 2,400 feet and the gardens are frequently irrigated. We have here simply an example of the fact that an abundance of moisture is favorable to vegetative growth, without tendency to force fruiting, while low moisture which is yet above the minimum at which the plant can live does force fruiting (9). Plants which were apparently about to die from extreme drought in 1924 had but very few or no blossoms even in the normal fruiting period.

ACTIVITY OF THE MOTH

As will now be shown, the normal habit of the moth is closely correlated with what we have termed the normal fruiting period of the plant. The moths fly to strong light such as that from a gasoline mantle lamp or lantern, a Coleman lantern of 300-candle-power having been used in this investigation. The author has never taken a moth prior to August 15. In the Barnes collection, however, are specimens taken between August 1 and 7 in the Santa Catalina Mountains, by Poling.* From August 15 to about September 15 they may be readily taken on favorable nights. In our experience, however, they have appeared neither earlier than 9 p. m. nor later than midnight. The observations of Moreland (10) agree with ours on this point. The latest definite date recorded on specimens taken in nature is September 26.†

No data whatever, other than the records of capture of moths just discussed, have been obtained on emergence of the moths in nature. In

*Courtesy of Mr. Foster H. Benjamin

†Koebele collection, California Academy of Sciences, by courtesy of Mr. E. P. van Duzee.

1921 a half-dozen bags of mosquito netting 4 feet in diameter and 6 feet in depth, with iron rings bound in the openings, were inverted over six individual Thurberia plants showing bollworm infestation of the previous year. It was hoped thus to secure freshly emerged moths, but none were taken by this means, and before the season was over all the plants were destroyed by storms, floods, or cattle.

OVIPOSITION

The oviposition records of 4 years bear out even more strikingly the correlation mentioned. The eggs, though small, are white and are deposited in conspicuous positions, such that it is a simple matter for one accustomed to their appearance to find them. They are, with but very few exceptions, placed on the tips of flower bracts or on the pointed tips of the leaves of *Thurberia*, and on the upper surface. The few exceptions consist mainly of instances in which eggs are deposited on the angles caused by destruction of portions of leaves. In one lot of 164 eggs, 105, or 64 percent, were deposited on leaf-tips, and 59, or 36 percent, on bracts. In another lot of 181 eggs collected at random, 180 were on leaves and but one on a flower bract, though from the habits of the larvae, one might well expect the reverse. The earliest dates on which eggs have been found are as follows: August 17, 1921, August 18, 1922, August 14, 1923, and August 15, 1924. Pierce and Morrill (12) mention the fact that eggs are sometimes found in clusters of two, or still more rarely, three. We do not believe, however, that this is an exception to the rule of laying eggs singly. Repeated observations have shown that almost never do the eggs thus placed side-by-side hatch the same day, and it appears therefore that they were deposited singly at different times and were contiguous merely by accident. Only 10 eggs, five pairs, of the above lot of 164 were thus deposited, while of the lot of 181 eggs, only 4, two pairs, were thus placed.

The incubation period determined by various means is 6 days. On one occasion some eggs were deposited in a box containing Thurberia leaves in which several moths were held captive over-night. At other times all eggs were collected from a given plant on a certain day, and the following day eggs deposited during the intervening night were collected and kept under observation. These observations gave the same results, and are further corroborated by out-of-door records. Taking August 15 as the beginning of oviposition larvae would appear August 21, and since August 25 is the approximate date when flowering of *Thurberia* begins freely, it will be seen that oviposition is well correlated with the appearance of buds, in which the newly-hatched larvae begin to feed.

In 1924 the abnormal climatic conditions already stressed resulted in great irregularities in oviposition. On August 16, for example, when the first eggs were noted north of Stone Cabin Canyon a single egg was found in a certain area where none occurred the day before, indicating normal oviposition. Three quarters of a mile distant in the same wash, where there was evidence of a light, local shower, a few eggs were noted. Two and a half miles beyond this wash, nearer the mountains and at an altitude at least 400 feet above the other areas, 181 eggs were gathered on this date from a small group of plants, 32 percent of which already had hatched, indicating an abnormally early oviposition at that point. On August 19 in the Sierrita Mountains, a few miles directly across the Santa Cruz Valley and at about the same elevation, half a dozen eggs were seen in the course of inspection of some hundreds of Thurberia plants, indicating late oviposition. No such irregularities were noted in any previous year.

In the very dry area so deficient in eggs and in material for larval food in 1924, one could but wonder whether most of the moths were remaining in the pupal cells on account of the drought and whether, if so, they might issue the following year. Webb (15) shows that one of the specimens sent in 1918 to Brownsville in the pupal stage actually issued, not in 1919, as did 9 others, but on August 28, 1920, nearly 2 years after pupation.

With this indication of its resistance, and since the bollworm infestation in 1925 in this identical area appeared to be about normal, it is quite possible that some moths spent some 22 months in the pupal stage. On the slightly later dates recorded for 1921 and 1922 it may be noted that no examinations were made on the preceding 3 or 4 days and that eggs were somewhat more numerous than on the earlier dates of other years, indicating that oviposition had actually begun a little prior to the recorded dates. The beginning of oviposition, therefore, falls with surprising regularity on or very near the middle of August. At this date there is but little outward evidence that the wild cotton plants are about to bloom, though close inspection reveals the presence of some very small buds (squares). Six days later when the first larvae hatch small buds are numerous. Eggs become increasingly numerous up to the first week of September. Egg collections made in September show a rapid increase in percentage of hatched over unhatched eggs. On September 9, 1920, for example, of 164 eggs examined 66, or 40 percent, were hatched, and 98, or 60 percent unhatched. On September 16, 1921, of 100 eggs examined, 89 were hatched and 11 not hatched. Therefore, if the egg stage be 6 days, as will appear, 89 percent of the eggs laid up to September 16 had been deposited by September 10.

RELATIVE ATTRACTIVENESS OF COTTON AND *THURBERIA*

In connection with oviposition an effort was made to determine the relative attractiveness of *Thurberia* and *Gossypium* for the female moths. Nothing is known concerning the feeding of the moths. As their life span in the moth stage is probably somewhat less than 2 months, it is possible they do not feed. Further, their daily period of activity seems to be only 3 hours or less. They are very quiet throughout the hours of daylight and must be well hidden, as the author has found but two specimens in the open by day in the course of many hours of work among Thurberia plants. Moths in the laboratory or in screen cages outside can scarcely be made to move by flight during the day. The food plant on which the eggs are laid must necessarily have an attraction for the female moths whether there be any attraction as a food or not. First attempts to test this matter as between *Thurberia* and cotton *(Gossypium)* consisted in placing moths taken at lights in a large screen cage containing both plants. The test resulted in complete failure, however, as the moths will not oviposit in confinement. Moreland (10) reports the same result. We have one doubtful record of such oviposition and that upon cotton. The egg was not discovered, but a larva was found later, the presence of which could not otherwise be satisfactorily accounted for. In 1922, 1923, and 1924 efforts were made to conduct a field test of attractiveness of cotton for oviposition. The plan was to grow a small patch of cotton located in such close proximity to infested *Thurberia* as to offer opportunity for oviposition on either. For this purpose it was necessary to have tillable soil and irrigation water as well as the continued presence of some one who could irrigate the cotton as required. The location chosen was the ranch headquarters of Wm. Nicholson in Stone Cabin Canyon of the Santa Rita Mountains, 9 miles east of Continental. This is the spot formerly known as McCleary's Camp,* Stone Cabin Canyon, so designated in much entomological literature, particularly that of Thurberia weevil and bollworm. The small plot of ground available is located on the bank of the wash, with *Thurberia* growing plentifully both upstream and downstream at distances of less than 100 yards in either direction. Moths have repeatedly been taken at night just across the wash, about 50 yards distant from the cotton patch..

In 1922, despite such care as could be given by the experimenter with headquarters 40 miles distant, cutworms and rodents destroyed two plantings. Efforts to transplant even small plants in August were unsuccessful and the test had to be abandoned for that year. In 1923 the

*This name is destined ere long to disappear from maps, and will mean nothing to coming generations of entomologists.

early part of the season was extremely dry, following a very dry winter, and there was insufficient water for irrigation. Of the two wells available, one was totally dry, and the other barely met the demands of the livestock. Copious summer rains fell in July and August, however, and some seed was planted July 24. This germinated quickly and grew very rapidly, but was not at a stage such as could be considered to constitute a fair test when oviposition was at its height, as there were no squares on the plants during that period. In 1924 a backward crop was carried through up to the usual rainy period, which would have made a good crop had normal rains fallen. Unfortunately this proved to be an exceptionally hot and dry summer throughout and only a poor crop resulted. Squares, blooms, and bolls were present, however, during the period of oviposition for the moths. Not an egg was deposited on the cotton plants, though moths were taken at lights just across the wash, about 50 yards distant. It must be added, however, that Thurberia plants in this and other nearby washes were in extremely bad condition, not only from drought, but from browsing by livestock, and, as a consequence only a very few eggs were to be found within a half-mile or more. This condition might be expected to force oviposition on the cotton plants. The whole season was one of such great irregularity, and so few moth eggs were deposited in many areas, that it is an open question whether a normal number of imagos emerged. In the meantime, approximately an acre of cotton in good condition was being grown for weevil experimentation at Agua Caliente, 16 miles northeast of Tucson, the site of Coad's weevil experiments in 1914 (4). This is within the normal range of *Thurberia*, but one night of lantern work on August 20, did not yield any specimens. Weekly, or more frequent, inspections of this cotton throughout two seasons have shown neither eggs nor bollworm larvae. It appears unlikely, therefore, that the female of *Thurberiphaga diffusa* will voluntarily oviposit on cotton. If this be true, there is certainly little danger of natural infestation of cotton by the Thurberia bollworm, since there is practically no other conceivable means by which an infestation would occur.*

HATCHING AND LARVAL HABITS

The larva makes its way out of the egg-shell by cutting a slightly oblong hole usually in one side of the larger portion of the egg just

*After this was in type reports were received from Federal inspectors to the effect that a number of Thurberia weevil infestations have been found in the domestic cotton crop of 1925 at different points along the Santa Cruz Valley. These infestations were most marked in the upper valley between the Santa Rita and Sierrita ranges of mountains, where *Thurberia* is not far distant from the fields. It is worthy of note that thus far no Thurberia bollworm infestation has been reported.

above the base. The egg-shell is not devoured and remains in position for a considerable period, dead white in color, and as conspicuous as ever. From known habits of the older stages it seems probable that the majority make their way out of the eggs at night. They almost invariably do so in the laboratory, though on a very few occasions they have been observed to issue by day. The complicating factors introduced by confinement in jars might easily account for this variation. Immediately on leaving the egg the larva seeks food and shelter. It works downward and inward along the leaf or stem to an axil or fork, from which point it turns upward on an exploratory tour. Should it fail to find a suitable bud, small ones being preferred, it again turns downward and repeats this method of exploration until a satisfactory bud is found. This it at once enters, usually eating its way in on the side of the bud near the base. Rarely a small boll is first attacked. Sometimes the opening is made above the edge of the close-fitting involucre, other times by piercing the latter. An angle where the bract joins, affording some measure of protection, is sometimes preferred. Invariably in the field, whether in this or a more advanced instar, the larva guards against being carried to the ground through the shedding of the injured bud or boll by providing a bond of silk at the base of the flower stalk, holding it firmly to the parent plant. An injured bud almost invariably, and injured bolls commonly, break at this joint and would fall if not thus attached. Unless it fell in the shade the high temperature then encountered on the soil surface would prove fatal to the contained larva. Soil-surface temperatures reached 158° F. in southern Arizona in the summer of 1925 as shown by a recording soil thermograph. In 1924 a soil-surface temperature of 181° F. was taken in June with a reliable thermometer. A heavily infested plant is readily discernible at some distance owing to the numerous pendent buds and bolls, hanging by this silken anchor (Fig. 5). The bollworm sometimes spins silk about and over the bud, if the latter is nearly ready to open, and thus prevents the flower from opening. It is believed that normally the anchor silk is spun by the larva before entering the bud, though cage observations on larvae removed from their shelter in daytime and thus compelled to seek a fresh bud or boll by day sometimes show an interesting variation. In such cases the larva may be in such haste to get under cover that this precaution is neglected, but in most cases it will be found later that the larva has issued from its retreat under cover of darkness and has spun the usual anchor. No larva has ever been observed abroad on the plant by day, though, as will be shown, each consumes a number of buds and bolls. The change from one to another normally takes place during hours of darkness. The distance traversed by a newly hatched larva from the egg to the bud finally selected has been observed to be as much as 2 feet, but this does not indicate how many unsuccessful side trips may have been made before a suitable location was found. The entrance hole is usually left open and from it is ejected a yellowish frass. One small bud from 1/8 to 3/16 of an inch in diameter generally suffices for the first instar which extends over but 2 days,—sometimes 3 days in the laboratory. The first molt then occurs within the

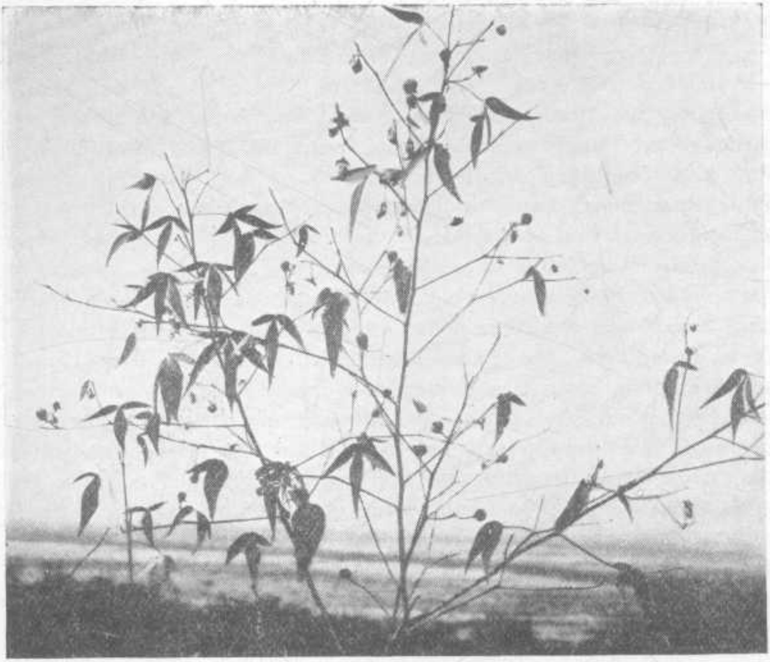

Fig. 5.—Portion of Thurberia plant showing numerous infested buds and bolls hanging by the silken anchors woven by the attacking bollworms as a safety measure.

now hollowed bud, after completion of which the larva makes its way to a fresh bud or small boll. Only rarely does a newly hatched larva attack a boll and then only a small and tender one. It could not be ascertained that there was any definite stage or instar at which the preference of the larva changes from buds to bolls. From one to four buds of various sizes may be successively attacked before selecting a boll, and occasionally a larva has been recorded as returning to buds after having eaten out a boll. Occasionally an entrance hole is partially closed with a web of silk, and the larva in this case is likely to be found parasitized, but we are not able to say that this is uniformly true. Such closing may in some cases be for better protection while molting, but it is not a regular practice. The bolls attacked are as a rule completely hollowed out. The average number of buds and bolls of *Thurberia* consumed by nine larvae successfully carried through the larval stages in 1923 was 3.4 buds and 4.1 bolls. In 1922, ten larvae carried through the bud-feeding stage consumed an average of 3.5 buds each, while five larvae recorded through the further stages of boll feeding consumed an average of 6 bolls each.

METHODS USED

A brief description of the methods of conducting the life history studies may be in order, inasmuch as both Townsend and Moreland experienced considerable difficulty in rearing larvae in confinement. Both were under the handicap of working in a camp laboratory, Moreland failing to carry any larvae through from egg to pupation. The present author did not find it possible to carry a large percentage of larvae through from egg to pupa in confinement and at the same time make the examinations necessary to determine instars accurately. Both Townsend and Moreland used tumblers or jelly glasses supplied with moist earth, as containers for the bolls with feeding larvae, and used cloth as a ventilating cover. By this method it is difficult to supply correct humidity, and dissatisfied larvae can cut their way out through the cloth covering. Too much ventilation keeps the air dry enough to destroy the succulence of the food, unless an excess of moisture is kept in the earth. After testing moist earth, a wad of moist cotton, and fresh Thurberia leaves, as sources of moisture in a closed tumbler, it was determined that leaves were most suitable. Jelly tumblers of low or bowl form with tight-fitting covers were used. In one of these were placed a number of eggs with several small buds of *Thurberia*. The next morning all were removed, hatched eggs were discarded, the bowl cleaned, unhatched eggs, fresh buds, and leaves being replaced in the jar. Each bud infested by a newly hatched larva was then isolated in a jelly glass with one or two fresh Thurberia leaves to supply moisture. After experience had shown at about what period the larva would likely seek fresh food, fresh buds or bolls were also placed in the tumbler when changes were expected and the old one was discarded after the larva had transferred. In case of removal of a larva from the boll for examination it was simply placed with fresh food and leaves. This method has the advantage that the entire contents of the tumbler can be removed daily, the jar cleaned, and material entirely fresh with exception of the infested boll put in. Determination of instars depended upon inspection of larvae by partial or complete opening of buds and bolls, and search in the refuse of abandoned buds and bolls for cast-off head capsules.

An abundance of *Thurberia* growing in both screened and introduction gardens supplied fresh food and also gave opportunity for observation of larval habits and life history on growing plants out-of-doors, but under protection of screen. By means of tests under screen it was found possible to infest these plants by placing upon them eggs of *Thurberiphaga* collected in the mountains. The method used succesfully was to collect portions of Thurberia leaves bearing eggs, and then to glue these portions to leaves of Thurberia plants under screen. Thus were obtained data corroborative and corrective of findings in the laboratory.

Under screen protection there was available also a supply of cotton being grown by the Plant Breeding Section. Beginning on cotton plants doubly screened, larvae well advanced in growth (probably mostly third instar) were placed on bolls. These larvae would attack and enter the cotton buds or bolls without hesitation, especially if they were placed within the bracts. If placed on the plants to shift for themselves they were somewhat baffled by the relatively complete enclosure of the boll by the large bracts. It was found that such larvae completed their larval growth in apparently normal fashion on cotton. With but a single exception, however, all bollworms thus completing their growth perished sometime between abandonment of the bolls for pupation and the normal time for emergence the following year. Whether or not this was due to irrigation which was rather frequent in the screened garden, undoubtedly resulting in the maintenance of a much greater degree of soil moisture than is normal to the sandy or gravelly, well-drained soils in which *Thurberia* grows, we attempted to test by another series of experiments. Three screen cages were provided, one inside the irrigated screened garden, another in the more heavily irrigated introduction garden, and a third on well-drained, gravelly, mesa soil where there was no irrigation and which was the nearest approach to the soil-habitat conditions of *Thurberia* afforded by the University Campus. In the season of 1921 many larvae that were seeking the soil for pupation were placed individually in small (2-inch) flower pots of fresh earth. Of these some died without entering the soil, some —too far advanced—pupated on the surface and a total of 38 entered the soil at once and presumably pupated. Three additional larvae spinning for pupation within old bolls were buried in soil in pots. These 41 pots were buried flush with the earth in the three cages as follows: Pots 1-10 on October 8 and pots 21-25 on October 10 in cage in introduction garden; pots 11-20 on October 8 and pots 26-30 on October 10 in cage within screened garden; pots 31-41 on November 26 in cage on mesa soil. It may be stated that in several instances the earth was carefully poured from the pots before they were buried and pupal cocoons found on the bottoms or sides of pots. A complete record of subsequent irrigations in the screened garden was not secured for the autumn months, but from February 16 to August 5, 1922, the garden was irrigated 14 times in addition to the natural precipitation. The irrigation record for the introduction garden was carried away, but the number of floodings would approximate a half-dozen. On the mesa soil a total precipitation of 6.91 inches was recorded from November 1, 1921, to July 31, 1922. Not one moth emerged from the cage on mesa soil, nor from the cage in the introduction garden. A single moth emerged in the screened-garden cage on September 4, 1922. Since all specimens perished in the other cages, and all but one in this cage, no conclusions concerning the effect of irrigation can be drawn. Since, on the other hand, in the latter cage one larva passed its entire life from egg to abandonment of the boll, and probably pupated normally in the soil, it is assumed to be most likely that this one emergence was from that normal pupation and that all in the flower pots perished. On September 23-25, 1922, all pots were taken up and the soil was examined to determine the fate of the pupae if possible. Pupae or cocoons were not found in all pots, possibly indicating death of larvae before pupation. Many were found, however, in such a state of disintegration as to indicate they had died in the early months of the pupal period, while in four pots from the screened garden, remains of four fully-formed moths with typical colors of the adult were found.

A repetition of essentially this experiment, but omitting the use of flower pots, allowing the larvae to enter the soil of the cages directly, will be described below. In the meantime other developments of the problem appeared to indicate that this insect might have less dangerous potentialities than had been supposed, and the attempt to determine whether irrigation would have a deleterious effect was postponed.

In early September, 1922, seven newly hatched larvae were confined with squares of cotton. Only one of these succeeded in entering a bud, and none survived. The one entered a very small square but on the next day was found dead in the jar, having only partially eaten the bud attacked. Failure to gain access to the buds may have been due to two factors; first, the pubescence of the cotton squares, and second, the relatively complete enclosure of the bud within the bracts. Thurberia buds are free from pubescence and the bracts are slender and in no sense enclose the buds. There is no point to calling them squares except by transfer of the term from cotton to a corresponding stage of the Thurberia bud. Actual observation of newly-hatched bollworms on the cotton squares showed that the pubescence offered a real obstacle to them.

Following this lead 100 eggs of *Thurberiphaga* were placed on cotton in the screened garden, it being felt now that the losses due to difficulty of entering the buds and to irrigation, cultivation, and unknown factors resulting in failure of moths to emerge in the cages rendered such a proceeding relatively safe. These eggs were attached in the manner above described and found satisfactory on *Thurberia.* No infestation whatever was detected as a result of this experiment in placing eggs of the bollworm moth on cotton. Following this, on September 29 a large number of bollworms in advanced stage of growth was collected in the Santa Rita Mountains. These were taken to the laboratory and sorted, those showing a desire to burrow being placed on the soil in the three cages and in the screened garden outside the small cage. Altogether, with mature larvae from indoor rearings, the number in each cage supposed to have entered the soil for pupation was 25, while approximately 46 entered the soil of the screened garden.

This planting was extended over 10 days from September 25 to October 5, the greatest number on September 30. Here again results were negative. Not a single moth emerged in 1923 from this "planting" of larvae. Had moths issued in the screened garden another test of choice between *Thurberia* and cotton might have resulted, since both plants were growing therein. Eight more moths from the mountains, not sexed, but known to have at least one female because of oviposition in confinement, were loosed on August 15, 1923, in the screened garden, not within the small cage, and all disappeared without a single egg being deposited.

The placing of eggs on cotton was repeated as follows: September 7, 1923, 75 eggs; August 24, 1924, 50 eggs; August 25, 1924, 50 eggs; September 5, 1925, 115 eggs. Thus in 4 years 390 eggs of *Thurberiphaga* have been placed on cotton in a manner proved satisfactory for transplanting eggs to *Thurberia* in the cages, and not one infestation has been found resulting.

In the meantime further laboratory tests were conducted, especially in 1924, with tame cotton squares and newly hatched bollworms. In jelly tumblers with hatching eggs were placed cotton squares but not *Thurberia,* so the hatching larvae were close to the only available food supply, which they must enter or perish. Of 27 larvae thus hatched, only four entered cotton buds. Of these one lived but 2 days, two others each lived 3 days, and the fourth lived 16 days. Why it then perished is not known. Larvae of its size transferred from *Thurberia* to cotton have an excellent chance of survival. Twenty-three of the twenty-seven died without entering a bud, one of them lying entangled in the pubescence. It seems safe, therefore, to conclude that infestation of cotton by *Thurberiphaga diffusa* is only a remote possibility, since practically the only method by which it might occur in the field would be through direct oviposition on cotton and subsequent infestation by the newly hatched larvae. Oviposition on cotton is believed to be unlikely, while it appears still less probable that infestation would follow if such oviposition occurred. The possibility of Pima cotton or other less pubescent varieties becoming infested is somewhat less remote than the infestation of the more densely pubescent varieties.

SUMMARY AND CONCLUSIONS

1. *Thurberia thespesioides*, so-called "wild cotton," in the mountains of southern Arizona, is commonly infested with the larvae of a Noctuid moth, *Thurberiphaga diffusa* Barnes, destructive to the buds and bolls of the plant. This insect is called in this paper the Thurberia bollworm.
2. The entire life history has been worked out. The insect is closely restricted to *Thurberia* as a food plant.
3. It has been suggested by several entomologists that this bollworm might readily transfer to cotton grown in valleys near the habitat of *Thurberia*, and thence become a destructive pest of cotton.
4. Experiments have been conducted to determine its potentialities as a cotton pest.
5. The insect is active only about two months of the year, early August to early October. It remains approximately ten months in pupal cocoons in the soil.
6. Its life history shows a striking correlation with the normal fruiting habit of *Thurberia*.
7. Moths would not oviposit on either cotton or *Thurberia* under screen. In the outdoor tests conducted the moths did not oviposit on cotton. Owing to conditions beyond control these tests were not wholly satisfactory.
8. Eggs transferred from *Thurberia* in the open to the same plant under screen resulted in normal infestations, but 390 eggs thus transferred to cotton gave no infestation.
9. Larvae in advanced instars will finish their feeding on cotton as a food plant, but there is no means by which such transfers are likely to occur in nature.
10. It is concluded that the Thurberia bollworm is not a potential pest of cotton, and that its continued presence in *Thurberia* need not give cotton growers concern.

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