ZEUGOPHORA SCUTELLARIS (SUFFR.)

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TWELVE FIGURES

The literature upon the beetles of the genus *Zeugophora*, except for descriptions of species, is very meagre. The life history of only one species is known and there are no published figures of the larvae and pupae of any species. Kaltenbach, however, gives a good brief description of the larva of *Z. flavicollis*.

The observations recorded in this paper were begun in the fall of 1912 at the University of Wyoming. The work was continued during the year but was interrupted the following June. After an interval of two years new material was secured which permitted completion of the work under laboratory conditions.

During my stay at the University of Wyoming I became interested in some larvae which were feeding upon the leaves of the cottonwoods which border the walks of the University campus. The leaves were badly discolored and as much as one-third or one-half of the green tissue of many of them had been destroyed by these larvae. It was for the purpose of identifying the beetle that I began the study of its life history which is briefly as follows:

LIFE HISTORY OF ZEUGOPHORA SCUTELLARIS

During the summer months the larvae work in the leaves beneath the epidermis, eating out the pulp and causing blackening of the parts affected. As stated above, a large part of the chlorophyll-bearing tissue may be destroyed in this way by the end of summer, thus rendering the leaf ineffective as a starch-

making organ. The larva may therefore appropriately be called a leaf miner. Late in the season, at the time the leaves fall, it emerges and enters the ground. After burrowing to a depth of between one and one-half and two and one-half inches below the surface, it excavates a little spherical cavity in which it coils up for the winter sleep.

About the last of May of the following spring (May 25-June 15) the larvae transform into pupae. As yet I have no definite records concerning the date of emergence of the adult under natural conditions, but the indications are that the duration of the pupa is about three weeks or possibly a month in cool weather. Under laboratory conditions it is about three weeks or less. The first beetles may therefore be expected to appear by the middle of June. There is reason to believe that they appeared as early as June 10 in the year 1913, which was a rather early spring for that locality. The number of pupae in the soil was considerably diminished before June 15 and the supposition is that they had metamorphosed. I found no imagoes at that time, however, probably because I did not know what kind of beetle to look for.

It has not been possible for me to return to Wyoming during the past three years so that it is not known whether the eggs are laid en masse or singly, upon the twigs and leaves. The fact that only one larva, as a rule, attacks a leaf might lead one to suspect that the eggs are laid singly. A number of beetles which were hatched from breeding boxes were kept in captivity and one of them laid eggs ten days after it emerged. It seems likely therefore that under normal conditions the eggs are laid upon the leaves and twigs during the latter part of June and the first part of July and that the larvae enter the leaves soon after, and begin their destructive work.

The adult beetles, as might be expected, feed upon the leaves of the cottonwood. They swallow the softer parts and discard the fiber.

EXPERIMENTAL RESULTS

During the fall of 1912 the larvae were discovered to enter the ground. Infested leaves were placed in breeding boxes stocked with sandy soil. As the leaves dried the larvae emerged and entered the soil in large numbers. It was thus possible to keep the larvae in the laboratory over winter.

Again, after all the leaves had fallen I dug beneath the trees and found the larvae in their burrows, and later digging, during the month of February, showed that they pass the winter as larvae.

The larvae which were kept in the laboratory were neglected and many of them died from lack of water. A few transformed

Fig. 1 Photograph of breeding boxes. They consist of a box $14 \times 18 \times 4$ inches, and contain sandy soil. Each box has a cap similar in all respects to the box, except that it is roofed over by black cloth, to permit good ventilation. Pint mason jars are screwed into holes in the sides of the cap. These jars permit light to enter, and insects upon hatching are attracted to them. The line of junction between the box and its cap is covered over by a band of black opaque cloth, which is tacked to the cap only, and hangs down over the seam.

to pupae as early as the first of March or the last of February, but if any beetles emerged from these pupae, they escaped. All other attempts to secure the adult insect during this year were likewise unsuccessful.

During the present year much better results have been attained. Larvae received from Wyoming by mail, were allowed to enter the soil of breeding boxes (fig. 1). They were watered once per week during the year. On March 1 they were still larvae. On March 20 one half or more had changed to pupae. On April 4 the first adult beetle appeared. These data indicate that the duration of the pupa under laboratory conditions is about three weeks. Other evidence on this point confirms the above statement. Six larvae were placed in a breeding box on

April 15. Two of them changed to pupae before April 20. One of these pupae emerged as an adult on May 7, making the duration of the pupa about three weeks or less.

Since the first pupae were found, under natural conditions, on May 25, and since the number of pupae in the soil was considerably reduced before June 15, it would seem that the duration of the pupa under natural conditions is also about three weeks.

The following table gives a record of the date of appearance, and measurements of beetles as they emerged from the breeding boxes.

DATE OF EMERGENCE	NUMBER OF BEETLES	MEASUREMENTS
		<i>mm.</i>
April 4.....	1	3.5
April 5.....	1	4.5
April 7.....	1	4.5
April 11.....	2	3.5 and 4.5
April 12.....	1	4
April 15.....	2	3.5 and 4.5
April 17.....	1	4.5
April 18.....	1	3.5
April 25.....	1	3.5
April 26.....	1	4.5
May 7.....	1	4.5

It will be noted that there are two sizes. Those marked 3.5 mm. varied between three and one-half and four millimeters while those marked 4.5 mm. varied between 4.5 and 5 mm. In all probability the larger ones are more nearly normal. The disparity in size is apparently not due to a difference in sex. The table also shows that beetles emerged during the period of a month under laboratory conditions.

Under normal conditions the first pupae were found on May 25 and the last larvae about June 15. It is apparent therefore that beetles may continue to emerge for a considerable period, and this fact should be taken into account in attempting to spray for the eradication of the pest.

MOULTING AND DEVELOPMENT OF PIGMENT

Incidentally some observations were made on moulting and the development of pigment. On April 15 the contents of one box were examined. A half dozen larvae, the same number of pupae, and two beetles were found. These two beetles were just emerging from the pupa case. They had freed all parts except the tarsi and a portion of each antenna. They were pulling and hauling energetically to free the feet. The remains of the pupa cases were crumpled into a shapeless film entangling the feet.

At this time the black pigment had not yet appeared. The beetles were almost uniformly straw-color except the elytra and antennae which were slightly brownish. On being placed in a lighted room they attained the black pigment within twenty four hours. It may be that light and oxygen are factors in the production of pigment, but pupae exposed to light do not develop pigment. All beetles were quite dark when they emerged from the soil, although the black became more intense later. They seem to remain in the ground a day or so after moulting the pupa skin, possibly longer.

DETAILED DESCRIPTION OF LARVA, PUPA AND IMAGO

Kaltenbach in his *Pflanzenfeinde* ('74, p. 544) gives a good brief description of the larva of *Z. flavicollis*. He states also that the metamorphosis takes place in the earth and that the summer brood appears in May of the following year. He gives no figure of the larva and his is the only reference in biological literature to the early stages of the *Zeugophora*. Up to the present time there has been no published description of the pupa of any member of this genus. Kaltenbach says of *Z. scutellaris* "Wurde von Apotheker Hornung und Dr. Suffrain auf *Populus nigra* gefunden. Ersten Stände unbekannt."

THE LARVA

The larva, when full grown, measures between 5 and 8 mm. in length. Seven millimeters may be considered the normal length for the species. It may be supposed that the larvae continue to feed and grow until the supply of food is cut off by the falling of the leaves. They seem to be unharmed by the autumn frosts.

The color of the larva varies from yellowish or straw to white, except the head, which is brown.

The body is flattened (depressed) in the dorsiventral plane. Twelve thoracic and abdominal segments can be counted. The abdomen ends in a slender tip which may represent an additional segment. The first thoracic segment consists of two annulae. The segmentation throughout is deeply marked and the strong lateral prolongations of the abdominal segments seem to be characteristic.

Thoracic appendages are wholly undeveloped or do not appear on the surface.

The antennae are well developed but short, and are directed straight forward. Each consists of four segments, counting a short, thick basal segment.

The mouth parts are best described in connection with the figures (figs. 5 and 6). They are similar to those of other biting insects except that each part has interesting characteristic features. The labium consists of the mentum, sub-mentum and gula, but it bears no palpi. The maxillae appear to be immature and the typical parts are not clearly defined in preparations examined. The three-jointed maxillary palpi are well developed. The mandibles have a smooth knife-blade-like cutting edge and are beautifully hinged at two points, one dorsal and the other ventral, as shown in figures 5 and 6. The external and internal mandibular muscles are shown in figure 5. It is to be noted that the muscle fibers are not inserted directly into the mandible but are joined to it by a tendon of connective tissue. The labrum has a scalloped or incised edge and consists of two lobes, as shown in figure 5.

The entire body is sparsely bristled, as indicated in figures 2 and 3. There are two pairs of bristles on the lateral margins of the head. The ventral surface of the head bears four pairs. The first thoracic segment has three pairs of bristles situated dorsally, and two laterally. Four longitudinal rows of bristles occur on the dorsal surface of the larva and two rows on the ventral aspect (figs. 2 and 3). Each lateral prominence is tipped by a strong bristle. Figure 4 shows the arrangement of the bristles on the abdominal segments as seen in cross section. Most or all of these bristles apparently assist in locomotion.

In pointing out the characteristic features of the larva which are most readily recognized one should perhaps call attention to the depressed body, the strongly developed lateral projections of the abdominal segments, and the arrangement of the bristles, all of which can be seen at a glance.

According to Professor Aven Nelson of the department of botany at the University of Wyoming, the larva prefers *Populus acuminata* but is also found upon other species in the West. He writes as follows:

I beg to state that the larva seems to prefer *Populus acuminata* (Rybd.), the Colorado cottonwood, though I am inclined to think that it occurs in the leaves of other species. The species native along our streams is *P. angustifolia* (James), and in some of the lower altitudes of the state there is also a broad-leaved cottonwood, *P. occidentalis*. The latter I am quite sure is infested with the beetle but I am not sure that *P. angustifolia* is.

In Europe, according to Suffrain, the adult beetle *Z. scutellaris* feeds upon *Populus nigra*.

THE PUPA

The pupa is strikingly like the imago in anatomical features, though the parts are less sharply and gracefully outlined. This, of course, is the usual condition of pupae in general, and is to be expected in an immature and quiescent insect (see fig. 7).

The pupa is yellowish or straw colored. At first there is no indication of the dark pigment of the adult but before the final metamorphosis the antennae and elytra begin to take on a

brown color. The head and prothorax are bent sharply forward and the antennae pass backward and dorsally beneath the pro- and meso-thoracic legs. The mouth parts approach those of the adult beetle in structure but the mandibles are larger and have a smooth outline, without teeth. The adult toothed mandibles can be seen within, however, as the time for the emergence of the beetle approaches.

The characteristic prothoracic humps are evident. The broad tarsal pads which are so striking a feature of the imago are clearly outlined in the tarsi of the pupa. The tip of the abdomen has a complicated system of plates, most of which are shown in figure 7. The larval skin normally remains attached to the tip of the abdomen but it can be removed without difficulty. Three bristles are situated in a triangle over each eye and four pairs of large symmetrically placed bristles extend backwards from the tip of the abdomen, as shown in the figure. There are numerous other bristles on the body but they are smaller and seem to be of another character.

When disturbed in its burrow the pupa moves its abdomen actively and wriggles about more or less.

The characteristic features seem to be the broad tarsal pads, the thoracic prominences, and the bristles over the eyes and on the tip of the abdomen.

THE IMAGO

For the original description of *Zeugophora scutellaris* reference should be made to *Entomologische Zeitung zu Stettin*, vol. 1, 1840, page 99, by Suffrain. The species was redescribed by Lacordaire in his "Monographie des Coléoptères Subpent meres Phytophages," vol. 1, 1845, p. 236. Another short description of the beetle is given in "Proceedings of the Academy of Natural Sciences of Philadelphia," 1873, page 23, by G. R. Crotch (and M. A. Cantab). These descriptions do not agree in all particulars. Suffrain gives the color of the lighter parts as bright yellow, while Crotch describes it as testaceous yellow. There is a considerable reddish tint in the specimens with which I worked.

Suffrain gives the size as 2 to $2\frac{1}{8}$ lines which is practically 4.5 mm. Judging from my material the adult beetles vary considerably in size, but two sizes clearly predominate, the smaller ones measuring a scant 4 mm., while the larger ones measure 4.5 mm., or slightly above.

The prothorax has the conical prominence on either side, which is so characteristic of the genus *Zeugophora* (fig. 8).

The color markings are striking; the head, prothorax, mesothorax, scutellum and legs are straw or amber, while the metathorax, abdomen and elytra are black. The antennae are composed of eleven segments, the first three of which are usually amber or straw, the fourth brown and the remainder black. The eyes and mandibles are black.

The most characteristic structural features, aside from the prominence on the prothorax, are found on the legs. There is a pair of spurs on the distal end of the tibia (figs. 10 to 12). The tarsus is four-jointed, the penultimate segment of which bears a very large cloven or bifid pad, upon which the insect walks. This pad is covered by a dense coating of long bristles (figs. 10 to 12). The elytra are coarsely punctate and the entire body is sparsely pubescent except the tarsi, which are hairy or bristly.

THE EGG

Eggs were secured from only one insect, although a considerable number were kept in captivity and fed upon leafy branches of the cottonwood. The egg is microscopic and appears to be surrounded by an extra envelop and filament similar to that of the decapod-crustacean's egg. If this observation is correct it appears to be unusual.

Judging from the fact that only one larva inhabits a leaf I have thought that the eggs may be laid singly, although this is mere supposition. Kaltenbach claims to have seen two or three larvae of *Z. flavicollis* in a single leaf in Sweden.

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PLATE 1

EXPLANATION OF FIGURES

2 Dorsal aspect of larva outlined by camera lucida showing general appearance. Note especially the number and arrangement of bristles and the sharp divisions between segments. The dotted line in the head represents a suture. The heavy black line is a chitinous bar in the dorsal wall of the head.

3 Ventral view of larva showing bristles, etc. The four pairs of bristles which occur on the ventral surface of the head are not indicated. The two black lines are chitinous bars, supporting the mandibular articulation.

4 Diagrammatic cross-section of an abdominal segment showing arrangement of bristles and outline of depressed body.

5 Drawing of head as seen from above, viewed as a semi-transparent object. *A*, Antenna; *C*, Clypeus; *L*, Labrum; *M*, Mandible; *Ma*, Mandibular articulation; *EM*, External mandibular muscle; *IM*, Internal mandibular muscle; *T*, Tentorium; *S*, Suture line between front and genae.

6 The head as seen from below, highly magnified. *A*, Antenna; *L*, Labium; *M*, Mandible; *MA*, Ventral mandibular articulation; *MAX*, Maxilla; *CB*, Chitinous bar supporting the mandibular articulation.

PLATE 2

EXPLANATION OF FIGURES

- 7 The pupa. Note conical prominence on prothorax.
- 8 The beetle. Pits of elytro and coloration not shown.
- 9 The antenna.
- 10 Entire prothoracic leg as seen from the side.
Note spine on the tibia and the bristled pulvillus.
- 11 Tarsus of prothoracic leg as seen from above, showing bifid pulvillus.
- 12 Tarsus of methathoracic leg as seen from the side.