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TWO CITRUS LEAF MINERS OF THE FAR EAST

CLAUSEN, C.P.

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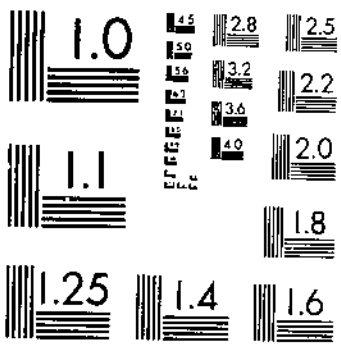


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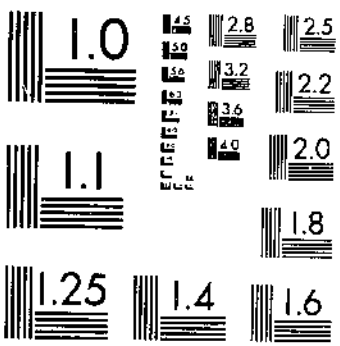


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TECHNICAL BULLETIN NO. 252 JULY, 1931

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

# TWO CITRUS LEAF MINERS OF THE FAR EAST

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CONTENTS

| | Page |
|---|---|
| Introduction | 1 |
| *Phyllocnistis citrella* Stainton | 1 |
| Food plants | 2 |
| Life history and habits | 3 |
| *Throscoryssa citri* Maulik | 5 |
| Life history | 7 |
| Parasites | 9 |
| Literature on leaf-mining Chrysomelidae | 10 |
| Means of distinguishing between infestations of *Throscoryssa citri* and *Phyllocnistis citrella* | 11 |
| Summary | 11 |
| Literature cited | 12 |

## INTRODUCTION

Among the insect enemies of Citrus which have not thus far gained a foothold in the United States are the leaf miners endemic to various parts of the Far East. The writer has had the opportunity of observing the more common one of these, a moth, *Phyllocnistis citrella* Stainton, in Japan, Taiwan (Formosa), China, India, and several other countries; and in Assam, India, he observed a coleopterous miner, *Throscoryssa citri* Maulik, previously unknown as a citrus pest and at the time undescribed. A general account of the work of these two species is given in this bulletin with directions for distinguishing between the infestations wherever they may be encountered.

## PHYLLOCNISTIS CITRELLA STAINTON

The common citrus leaf miner of the Far East, which is found in greater or less numbers on nearly every tree, is the minute lepidopteran *Phyllocnistis citrella*. This species occurs in abundance in Japan, China, Taiwan, Siam, the Federated Malay States, and India, and is also recorded from the Philippine Islands, Dutch East Indies, Burma, Ceylon, and Australia, and at Cape Town, South Africa. In Australia and South Africa it is apparently an introduction of relatively recent years.

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The Japanese form has heretofore been recorded as *Phyllocnistis saligna* Zell., and was so listed by the writer in a previous paper (*3*).[1] *Lithocolletis citricola* Shir. (*12, p. 89; 17, p. 330*), described originally from Taiwan, is now stated by Doctor Shiraki to be synonymous with *P. citrella*.

A comparative study was made by the writer of the larval and pupal characters of specimens from Japan, China, and India, and no basis for distinguishing between them could be found. Specimens of adults from Japan and India were forwarded to the Bureau of Entomology and examined by August Busck, who has declared them to be identical. S. Matsumura of the Hokkaido Im-

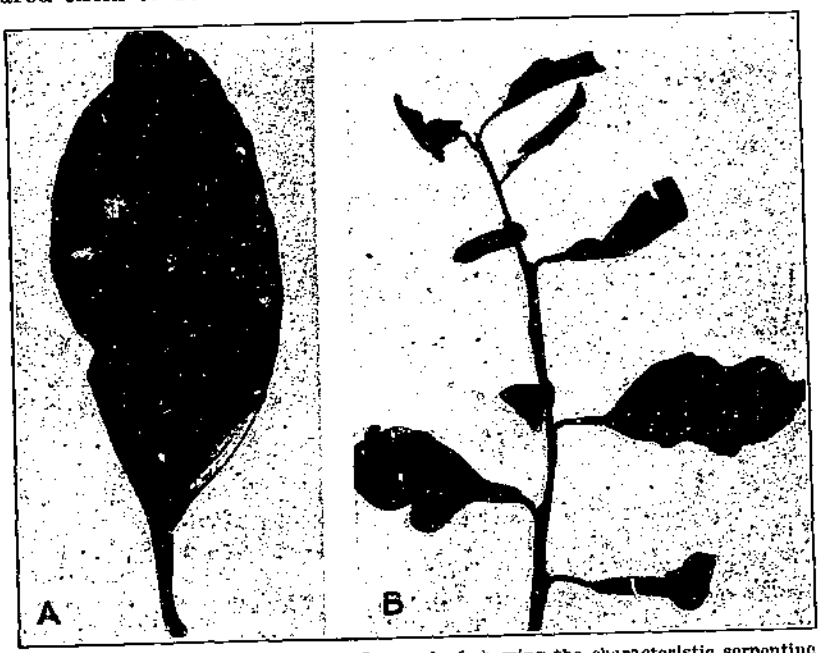


FIGURE 1.—*Phyllocnistis citrella:* A, Orange leaf showing the characteristic serpentine mine made by the larva; B, twig with the leaves curled owing to attack by this insect

perial University has recently expressed the same opinion, and T. Bainbrigge Fletcher, Imperial entomologist of India, has, in correspondence, called attention to the fact that the Japanese form is the same as that found in India, and that the true *P. saligna* Zell. is restricted in distribution to northern and central Europe, and to host plants other than citrus. It therefore appears that only a single species of Phyllocnistis, the one here treated, is involved in the attack upon Citrus in the various countries of the Far East.

### FOOD PLANTS

Although Citrus is the principal food plant of *P. citrella* this insect is said to occur also upon a number of other hosts. Kurisaki (*9*) lists it upon willow in Japan; and in India, Fletcher (*4*) mentions it as mining the leaves of *Aegle marmelos*, *Murraya koenigii*, and *Jasminium sambac*. Reinking and Groff (*14, p. 426*) record

[1] Italic numbers in parentheses refer to Literature Cited, p. 12.

it upon Loranthus in the Philippine Islands, and Sasscer (*16*) reports it as taken at quarantine upon Atalantia nursery stock from those islands. In Siam it occurs very commonly upon the various species of Loranthus which attack Citrus.

The injury to citrus trees by *Phyllocnistis citrella* is due to the mining of the leaves by the larvae, which results in the killing of considerable quantities of tissue. These mines may also be found at times on the young growing shoots. Typical examples of injury are illustrated in Figure 1 in which is shown the mine itself and the resultant curling of the leaves similar to that caused by aphids. When the number of mines becomes excessive and practically every leaf is attacked, as is often the case with nursery trees, the injury results in the stopping of the growth of the young shoots and improper functioning of the leaves, though seldom causing the death of the tree. The most serious attacks by this species were observed in the Federated Malay States where practically every leaf, particu-

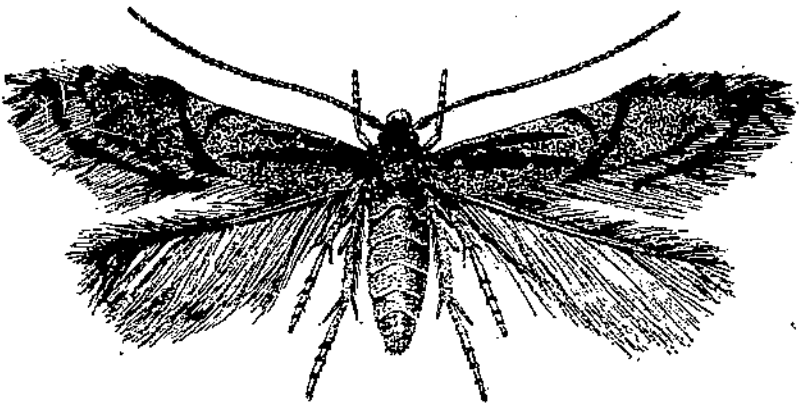

FIGURE 2.—*Phyllocnistis citrella:* Adult female. × 25

larly of the younger trees, contained several larvae. The mines are reported by Hill (*7, p. 7*) and Kurisaki (*8, 9*) to serve as points of infection by citrus canker (*Pseudomonas citri* Hasse).

## LIFE HISTORY AND HABITS

Under summer conditions a generation of this minute moth may be produced in six weeks, so the potential rate of increase is very great. Most of the injury, however, is inflicted by the first two generations in the spring. This species passes the winter solely in the adult stage (fig. 2), a habit uniform in the genus.

According to Kurisaki (*9*) approximately six generations are produced each year in southern Japan. The egg, larval, and pupal periods cover 9, 20, and 9 days, respectively, at Wakayama. In the district around Wakayama about 60 per cent of the larvae and pupae are parasitized by Chalcidoidea, the summer and fall generations being the most heavily attacked. At Yokohama the percentage of parasitisim observed by the writer in 1923 and 1925 was considerably below this figure, in fact less than 1 per cent of the generation reaching maturity at the end of July, 1928, was attacked.

The egg, which is 0.27 mm. in length, flat, and without sculpturing or covering, is laid near the midrib on the lower side of the leaf. The young larva enters the leaf immediately upon hatching and begins the formation of the characteristic serpentine mine. This is always continuous; and the larva, unlike that of *Throscoryssa*

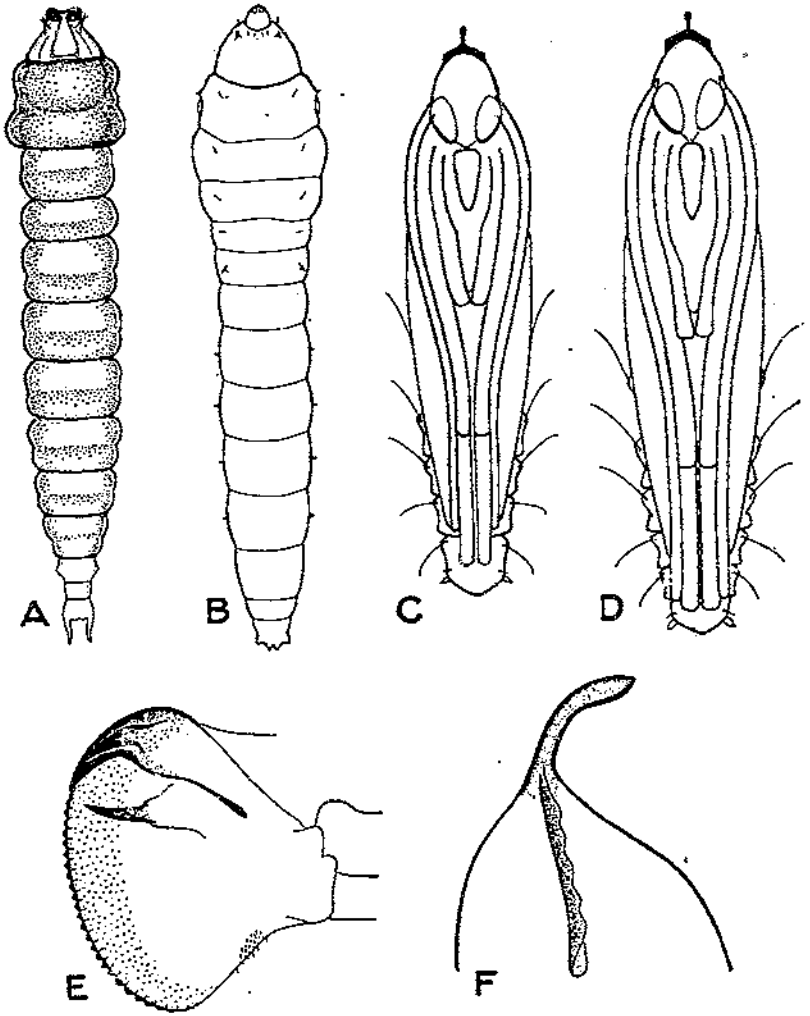


FIGURE 3.—Larval and pupal forms and parts of *Phyllocnistis citrella*: A, Final larval stage, dorsal view, × 25; B, prepupa, dorsal view, × 30; C, male pupa, ventral view, × 30; D, female pupa, ventral view, × 30; E, mandible of final larval stage, ventral view; F, head prong of pupa, lateral view

*citri*, never leaves the mine to form another. Feeding is restricted to the sap derived from the epidermal and adjacent layers of cells, and the glistening, transparent covering which remains clearly reveals the larva feeding beneath. There is no ingestion of leaf tissue by any of the larval stages.

The placement of the egg and the formation of the mine on the lower surface of the leaf is the normal habit as noted in Japan and Assam. Recent observations in Siam and other tropical regions, however, have shown that in these latter the greater part of the mines are found on the upper leaf surface, and this seems to hold true in all humid, tropical regions. In his account of the species in India, Fletcher (4) gives this as the normal position.

The larval stages are similar in form, though the head and thoracic segments of the earlier stages are proportionately larger. Presumably there are four feeding stages, though this has not been determined with certainty. The mature feeding larva (fig. 3, A), by a regular contraction and expansion of the body, is capable of movement within the mine only backwards and forwards, and when removed from the mine it is unable to accomplish any ordered locomotion.

At the point where feeding has ceased the epidermis of the leaf and the opposing layer of tissue are forced apart, to a greater extent than has been previously the case, by an arching of the body of the larva in conjunction with a rolling motion. On a flat surface this rolling from side to side, which may be done very rapidly, is the only mode of locomotion of which the prepupa is capable. No feeding takes place in the prepupal stage (fig. 3, B), and the mouth parts are designed specially for the formation of the pupal chamber and the lining of it with a thin web of silk. The pupation cell is usually placed at the margin of the leaf, the edge being drawn over so that three sides are formed of fresh leaf tissue and the fourth by the thin layer of dermal tissue and the whole lined with a delicate layer of silk. The exposed portion often has a distinct orange color. The male and female forms of pupa are shown in Figure 3, C and D.

Just prior to the time of emergence of the adult moth the pupa makes an opening at the anterior end of its chamber and forces its body partly out through this opening. This is effected by means of the stout curved prong upon the head (fig. 3, F), assisted by the heavy spines on the dorsum of the abdomen. (Fig. 4.) The cast skin is left in the above-described position after the emergence of the adult.

Emergence takes place largely during the early morning hours. The adults are nocturnal in habit and even in the case of a heavy infestation are almost never seen in the field. When confined under laboratory conditions they mate shortly after emergence and within six days begin oviposition upon the young foliage. The eggs are laid principally between 7 and 10 p. m. and to a lesser extent in the early morning.

## THROSCORYSSA CITRI MAULIK

In the early spring of 1925 the writer noted at Shillong, Assam, India, several orange trees heavily attacked by a leaf miner, the tunnels of which seemed to differ somewhat from those commonly seen upon Citrus in other parts of the East, and which are produced by the lepidopteran *Phyllocnistis citrella*. A closer examination showed that the larvae forming them were coleopterous, and adults

were later secured from isolated individuals. These proved to belong with the halticid beetles, and specimens forwarded to the British Museum through the Bureau of Entomology were examined by S. Maulik (*10*) and described by him as a new genus and species under the name of *Throscoryssa citri*. The fact that this species was not represented in the collection of the Agricultural Research Institute at Pusa would indicate that it is not of general occurrence.

Observations were continued during the following two years to determine the method of attack and the status of the species as a

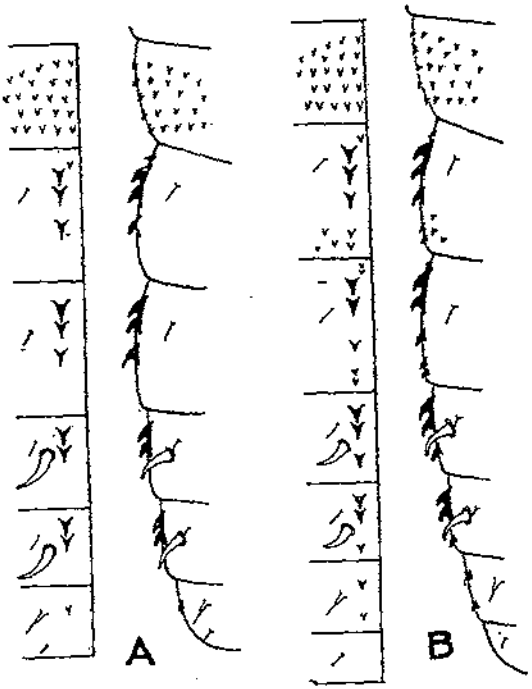


FIGURE 4.—Arrangement of spines on pupae of *Phyllocnistis citrella*: A, Spine arrangement on dorsum of male pupa; B, spines on dorsum of female pupa

Citrus pest. The foliage of some of the injured trees was almost entirely destroyed each year by the end of the larval feeding period, which was reached about the end of May. Owing to the fact that this beetle seems capable of becoming a pest of major importance under favorable conditions, it has been felt desirable to publish the available data regarding it. It has been found only in the Khasi and Naga Hills of Assam, and in these sections only locally. It appears to be an endemic species which has transferred its attacks from the wild varieties of Citrus to the cultivated forms. Citrus is grown only incidentally in these hills, however, as the temperature at elevations of 4,500 feet or more is too low for the commercial production of these fruits. No infestations could be found at the lower levels with temperatures comparable to the subtropical conditions, where the native orange is extensively grown.

### LIFE HISTORY

In the localities where *Throscoryssa citri* was observed only a single generation is produced each year. The adult stage (fig. 5) is attained about the end of May, and the beetles feed for a period of about one week, after which they disappear entirely from the trees. The summer, fall, and winter are passed in hiding in sheltered places such as rubbish heaps, weeds, under stones, and in the soil. Not a single one has thus far been found developing upon alternate host plants during this period. Emergence from hibernation takes place about the middle of March, and feeding begins immediately upon the newly developing Citrus foliage.

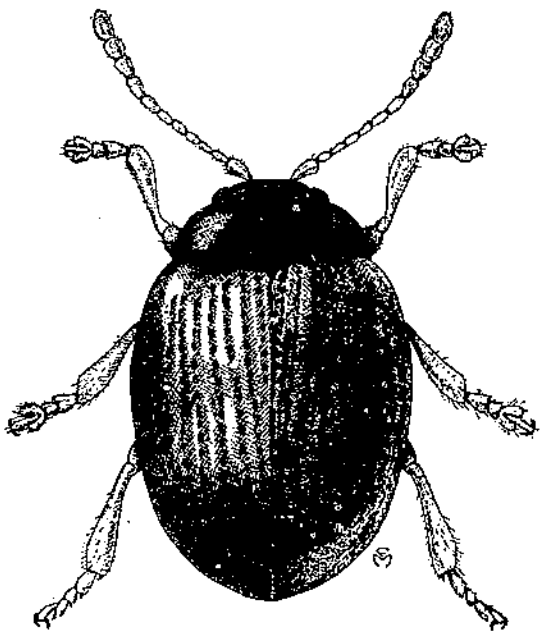

FIGURE 5.—*Throscoryssa citri*: Adult female, × 20

#### THE EGG

Oviposition begins from 7 to 10 days after the commencement of feeding in the spring. The eggs are placed largely upon the lower sides of the new leaves, which at this time are about one inch in length. As many as 39 have been found upon a single leaf in the field. Oviposition continues for approximately three weeks, and practically all beetles have disappeared from the trees by April 25. No complete oviposition records were secured, though 1 female in captivity deposited 49 eggs in 6 days.

The egg (fig. 6, A) of *Throscoryssa citri* is 0.75 mm. long, broadly oval, and yellowish. The entire portion not in contact with the leaf surface is covered with a white, waxy incrustation having reticulate surface markings. This incrustation extends slightly over the leaf surface around the margin of the egg and is most pronounced anteriorly. The egg, with the exception of the anterior end, is also covered with a heavy, irregular mass of brownish-colored excrementitious material. In the early part of the season, when there is little rain and the atmospheric humidity is low, this covering dries out to a considerable extent and becomes semitransparent. Later, during the early part of the rainy season, a fungus develops extensively in this covering, and the mycelium may entirely envelop the egg. So far as known this fungus exerts no detrimental effect. During this damp period the original color of the covering is greenish rather than brown. Hatching is effected by a transverse break in the egg chorion at the anterior end, and emergence is facilitated by the heavy mandibles of the young larva.

### THE LARVAL STAGES

The newly hatched larva wanders about the leaf surface for some time before effecting entrance, and the point finally selected is always on the lower surface. Burrowing about in the leaf tissue may be continuous for several days, and in such case the mine is serpentine in form and superficially similar to that of *Phyllocnistis citrella*. The continuation of this mine for any length of time, however, is unusual, and as the larva develops it frequently emerges from its mine, wanders about the leaf for a time, and then begins mining at another point, which may be on the same, or on another leaf. Emergence is always effected through the leaf epidermis on the upper side, whereas reentrance invariably takes place through the lower side. This wandering about the foliage takes place largely

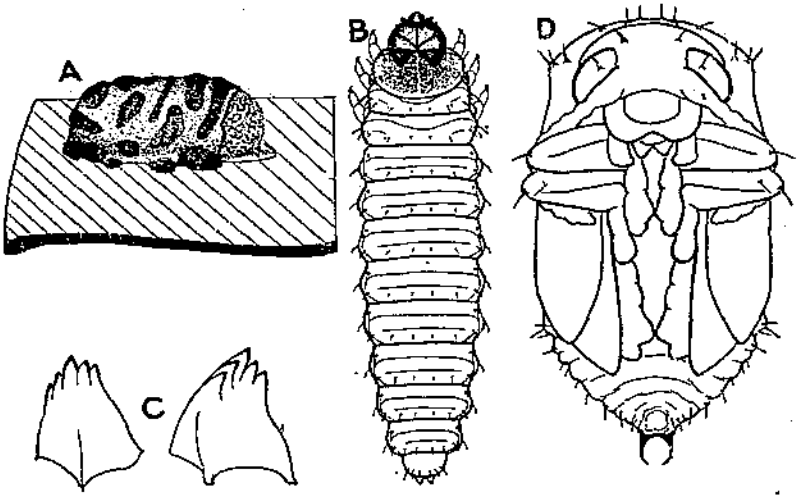


FIGURE 6.—Immature stages of *Throscoryssa citri:* A, Egg, showing waxy incrustation and the larger part covered by excrementitious material, × 70; B, third-stage larva, dorsal view, ×16; C, anterior and posterior views of mandibles of third-stage larva, × 180; D, ventral view of pupa, × 25

during the night and early morning hours when the atmospheric humidity is high and some moisture is present on the leaf. The formation of a new mine is always begun not later than 10 a. m.

Feeding by the larva of this halticid is of a much grosser nature than is that of Phyllocnistis. The entire leaf tissue between the upper and lower epidermal layers is eaten away; whereas the latter insect makes only a very delicate mine beneath the lower epidermis, and no tissue is consumed. The larva of *Throscoryssa citri* is able to cut through the lateral leaf veins without difficulty; and at times even the midrib may be crossed, in which case the distal portion of the leaf immediately dies. The affected leaves take on a yellowish color and, when the attack is heavy, fall from the tree. A single larva during its feeding period is capable of mining approximately 1 square inch of leaf tissue, and when there are very many larvae present the quantity of foliage consumed is considerable. The growth of the trees attacked is to a large extent prevented, as the young leaves are destroyed very soon after being formed.

The larval excrement occurs as a continuous, heavy black line at the middle of the burrow. In the case of the early-developing individuals this material soon dries out, but in the mines of those developing in the later part of the season after the rains have begun, extensive decay sets in, with an abundant development of fungus, which has a damaging effect upon the surrounding leaf tissues.

### PUPATION

When through feeding upon the foliage the larva, now completing the third instar (fig. 6, B), emerges from its mine, wanders about the leaf surface for a time, and then drops to the ground. It enters the soil, usually to a depth of about 1 inch, and there forms its pupation cell. This cell is oval with walls composed of soil particles apparently lightly cemented together. A period of about one week elapses before transformation to the pupal stage (fig. 6, D), which lasts from 10 to 12 days.

### HABITS OF THE ADULT

Several days are passed by the newly transformed adult beetle in the pupal cell in the soil, after which it emerges and immediately begins feeding upon the young foliage. The beetles are apparently somewhat gregarious and assemble in considerable numbers upon certain leaves. This, however, may be due to some preference for these leaves for feeding rather than to any inclination to congregate. The night is passed in the soil or among the weeds beneath the tree. The beetles emerge early in the morning and continue feeding until shortly after noon. The feeding by the adult is characteristic in that small, irregular portions are eaten from the leaf margin of young foliage, whereas of older leaves only the tissue of the lower surface is consumed, and this in irregular patches. The upper epidermal layer of cells remains but later dies. Numerous pellets of excrement are left around and upon these eaten areas.

### DURATION OF THE STAGES

Observation as to the length of time required for development through the various stages showed that from 8 to 9 days are required for the incubation of the egg; from 17 to 19 days cover the entire larval stage, of which only 10 or 12 are devoted to feeding, 7 days being spent in the soil preparatory to pupation; and finally from 10 to 12 days are passed in the pupal stage. Thus from 35 to 40 days cover the entire period of development from the egg to the adult. A week or more may be spent by the newly transformed adult in the pupal cell before it emerges. Following this a feeding period of about one week ensues, after which hibernation is begun without oviposition having taken place. The last of the beetles are seen upon the trees about the first week in June.

### PARASITES

Two species of Hymenoptera were found parasitic upon the larvae of *Throscoryssa citri* at Shillong. One of these, a braconid, was very abundant upon the foliage containing the miners, and oviposition through the leaf epidermis into the host larvae beneath was frequently observed. One female in the field deposited six eggs

within a period of one minute. One hundred mature larvae, taken from their cells in the soil, were dissected to determine the extent of parasitism. Fifteen of these were found to contain living braconid larvae in their early stages, and 32 revealed encysted eggs. It would appear that the parasite is either not well adapted to this host or that the eggs which became encysted were deposited too late to escape the phagocytic action set up as histolysis incident to pupation of the host progressed. The primary larva of this braconid is of the usual form, the caudal segment of the body being prolonged into a taillike respiratory organ.

The second species of larval parasite, a chalcidoid, was found to attack the early-stage larvae in the mines. Death of the host takes place in situ, and the entire contents of the body are consumed. Pupation takes place within the dried and darkened skin of the host.

## LITERATURE ON LEAF-MINING CHRYSOMELIDAE

The great majority of the Chrysomelidae feed in the larval stage externally upon the leaves or roots of various plants. Others burrow in the roots and a relatively few in the leaves. Among the latter are included species of the halticine genera Chaetocnema, Epitrix, Dibola, Hippuriphila, Mantura, Mniophila, and Phyllotreta, according to the lists given by Frost (*5*) and Needham, Frost, and Tothill (*11, p. 182*). Argopus, Argopistes, and Sphaeroderma are also reported to have the same habit.

Reed (*13*) has recently published an extended account of the biology of *Dibolia borealis* Chev., in which the life history is given in detail, and the various stages are figured. *Hippuriphila modeeri* (L.) was reared by Frost from the leaves of certain species of Rumex, this being the only feeding record for the genus. *Mniophila muscorum* Koch, a European species, mines the leaves of Plantago, Teucrium, and Digitalis. Chittenden (*2*), in his account of the habits of Phyllotreta, lists *zimmermanni* Crotch, *liebecki* Schaef., *oregonensis* Crotch, and *aeneicollis* Crotch as having the leaf-mining habit, and Frost adds to this list *chalybeipennis* (Crotch.), *nemorum* L., and *vittula* Redt. The greater part of the species of this genus feed at the roots rather than in the leaves. The food plants of many Halticidae are listed by Beutenmüller (*1*).

The life histories of all the leaf-mining flea beetles are practically identical, there being usually a single generation each year (though some species have two or three) with the adults hibernating during the winter, emerging in the spring or early summer, and passing through the immature stages in a period of from three to six weeks. Pupation takes place in the soil.

In his general account of the habits of *Phyllotreta zimmermanni* Riley (*15*) states that the eggs are deposited along the midrib on the upper surface of the leaves of Lepidium and that the larvae enter from the lower side. As development proceeds the larva may leave its mine without apparent reason and reenter the leaf at another point, or go to a new leaf.

In Reed's account of *Dibolia borealis* the life history and habits as given correspond quite closely to those of *Throscoryssa citri*. The egg has a protective or concealing covering of excrementitious material, though no mention is made of a waxy incrustation on its

surface. The excrementitious covering is found also in species of Altica but more lightly and in the form of streaks, though even this is usually lacking in the case of *A. bimarginata* Say (*18*). In habit *D. borealis* differs from *T. citri* in that the egg is deposited in a depression in the leaf tissue eaten away by the female beetle, and, though the mine is usually continuous for the entire feeding period, when a larva leaves the mine and reenters the leaf it makes a transverse slit in the upper epidermis and through this gradually works its way into the interior. The larval stages as figured bear a strong resemblance to those of *T. citri*.

In his account of convergent development in leaf-mining insects Frost (*6*) discusses the origin of this habit in the various orders, and states that the habit of leaving the mine and reentering the same or another leaf is one of the means of avoiding the accumulating frass in the mine, though the habit probably originated through the need for fresh food rather than for the reason given. He states, however, that this method of disposing of the frass is developed only occasionally in the Diptera Lepidoptera, and Hymenoptera, and not at all in the Coleoptera.

## MEANS OF DISTINGUISHING BETWEEN INFESTATIONS OF THROSCORYSSA CITRI AND PHYLLOCNISTIS CITRELLA

While *Thoscoryssa citri* is known to occur only in a very limited area in India as compared with the general distribution of *Phyllocnistis citrella*, throughout the Far East it is desirable that ready means of distinguishing between the infestations in the field should be known.

The mine of *P. citrella* is serpentine and continuous from the point of entry of the newly hatched larva to the pupation cell, and the cast pupal skin remains partially extruded from this cell after the emergence of the adult. In contrast to this the mine of *T. citri* is irregular and broken, and with the entrance and exit holes distinct. Feeding is much more extensive and all the leaf tissue between the two epidermal layers is eaten, the larva therefore being visible in the mine from both sides of the leaf. Decay of the leaf frequently follows, which very seldom results from the feeding of Phyllocnistis. The epidermal layers often fall away following this decay, thus producing linear holes in the leaf or dead areas at the margins.

Infestations of *T. citri* show the conspicuous eggs, feeding larvae, and adults on the tree at the same time, whereas those of *P. citrella* reveal only the feeding larvae, prepupae, and pupae, the eggs being practically invisible to the naked eye and the adults seldom seen. The larva of the former is larger, with a black head and the legs normal, whereas that of *P. citrella* is flattened, without legs, and the head is lighter in color than the body. The various stages of Throscoryssa may be found upon the tree only from the latter part of March to early June, whereas Phyllocnistis is present throughout the growing season.

## SUMMARY

Among the citrus insects as yet not found in the United States are the two leaf miners *Phyllocnistis citrella* Stainton and *Throscoryssa*

*citri* Maulik, the former common and widespread and the latter newly discovered and known only from a limited district in India.

*P. citrella* was formerly recorded as *P. saligna* Zell. when found in Japan, but *saligna* is now known to be limited to northern and central Europe and to hosts other than Citrus. *P. citrella* has other host plants, but has been found principally upon Citrus, which it injures by mining in the leaves. The insect hibernates as a moth, and there may be as many as six generations each year in southern Japan.

*T. citri* hibernates as a beetle in sheltered places and has but one generation a year. It is not known to have any other host but the varieties of Citrus. The larvae eat out the tissue from between the two leaf surfaces, frequently leaving the leaf by an exit hole in the upper surface and reentering the same or another leaf through the under surface. Pupation is in a cell in the ground. The adults feed gregariously, eating out irregular portions from the margins of the young foliage and the tissue from the lower surface of the older leaves. From 35 to 40 days cover the entire period from the placement of the egg to the emergence of the adult. The beetles are not seen after the first week of June. Two parasites, a braconid and a chalcidoid, were found to attack the larvae of *T. citri*. A résumé is given of the literature on leaf-mining Chrysomelidae.

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