U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 68.
L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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Deciduous Fruit Insect Investigations.

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[a] Transferred to another branch in the Bureau.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., July 20, 1909.

Sir: I have the honor to transmit herewith, for publication as Bulletin No. 68, nine papers dealing with deciduous fruit insects and insecticides. These papers, which were issued separately during the years 1907–1909, are as follows: The Pear Thrips, by Dudley Moulton; The Spring Canker-Worm and The Trumpet Leaf-Miner of the Apple, by A. L. Quaintance; The Lesser Peach Borer, by A. A. Girault; The Lesser Apple Worm, by A. L. Quaintance; Grape Root-Worm Investigations in 1907, by Fred Johnson; Demonstration Spraying for the Codling Moth, by A. L. Quaintance, S. W. Foster, Fred Johnson, and A. A. Girault; The Grape-Leaf Skeletonizer, by P. R. Jones; The Peach-Tree Barkbeetle, by H. F. Wilson.

Respectfully,

L. O. Howard,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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[a] The nine papers constituting this bulletin were issued in separate form on June 10, July 6, October 15, and October 17, 1907; January 8, April 24, and April 29, 1908; and January 20 and February 11, 1909, respectively.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

U. S. D. A., B. E. Bul. 68, Part I (Revised). D. F. I. I. September 20, 1909.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE PEAR THRIPS.

(*Euthrips pyri* Daniel.)

By Dudley Moulton.

Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

This paper brings together the results of an investigation of the life history, habits, natural enemies, and methods of control of the pear thrips (*Euthrips pyri* Daniel), a pest of deciduous fruit trees in the San Francisco Bay region of California. The investigation was undertaken at the request of the Santa Clara County board of supervisors, who furnished the funds and liberally granted necessary facilities for a thorough and scientific study, and was carried out in the Santa Clara Valley, where the thrips seemed to be at its worst. The investigation extended through a period of fifteen months, from February, 1904, to April, 1905.[a]

The writer offers this paper rather as an introduction for future work than as a completed account, and it is intended especially for the fruit grower, that he may understand the nature of the insect and its injury. The alarm felt for the safety of the deciduous fruit industry, which the pear thrips caused during 1904 and 1905, in the light of our present knowledge need not again be experienced, and, although no effective means of control are yet offered, a knowledge of the life habits should do much to clear away the uncertainty usually following the first appearance of a destructive pest in any locality.

OCCURRENCE AND DISTRIBUTION.

The pear thrips is known to exist in the San Francisco Bay counties and along the Sierra Nevada foothills, but it is not known how widely the pest is distributed outside of these localities. It is still a question whether the insect is a native of California or an introduced form. The pear thrips may have had some indigenous plant, such as the

[a] The writer wishes to acknowledge the work of Mr. Earl L. Morris and Mr. C. T. Paine. He is indebted also to Prof. W. R. Dudley, head of the department of systematic botany, and to Dr. G. H. Pierce, of the Leland Stanford Junior University, for literature and helpful suggestions, and finally to Prof. Vernon L. Kellogg for his ever helpful suggestions and encouragement.

wild plum or cherry, for its original food plant, and later, as large fruit-growing districts were developed and as the insect found more and better food, it may have changed its feeding habits from the wild to the cultivated plants. This would be a not unusual change. On the other hand, it may have been imported and, finding conditions favorable here and no effective natural enemies present, may have increased and spread rapidly.

In 1904 the pest was thought to be strictly local in the Santa Clara Valley, but in 1905, when the insect had become better known, it was found to be widespread in the San Francisco Bay regions and its ravages were being felt in fruit sections in other than this one valley. A peculiar blighting of blossoms had been commonly observed in several localities in the Santa Clara Valley previous to 1904, and this blighting was invariably followed by an almost complete failure of crop. Its cause was not at first explained, for trees were injured within a very few days and the insects, as it happened, were gone before the owner was aware of the injury.

The pear thrips seems to have reached a maximum in numbers during the season of 1905. Large orchard sections, often miles in length, suffered an almost complete failure of crops and these worst infested areas were in the heart of the best fruit sections of the valley. All of this loss, however, can not be charged to the thrips, for there occurred unusually heavy and driving rains during the blossoming season of this year, and it was often impossible to determine the relative amount of injury caused by the thrips and that caused by rain, except where thrips were found feeding before the storms came on. The season of 1906 proved to be a more hopeful one. Thrips, fewer in numbers, were late to appear, and the early injury to buds was not so apparent. The trees blossomed almost in the normal way. The later injury to fruits, however, was quite as noticeable. The scab on mature prunes—the never-failing evidence that thrips have been feeding in the spring—depreciated the value of the fruit in all of the thrips-infested regions.

NATURE AND EXTENT OF INJURY.

Injury to plants is the direct result of the feeding and ovipositing of the thrips.

DESCRIPTION OF THE MOUTH PARTS.

The mouth parts of thrips project from the lower posterior side of the head and have the appearance of an inverted cone (fig. 1). The mouth opening is in the small distal end, and through it the stylets or piercing organs are projected when the insect is feeding. The rim at the tip is armed with several strong, chitinous points, which figure prominently in tearing open the plant tissues. The insect first pierces

the plant epidermis with the stylets, then, moving the cone tip backward and forward, it enlarges the opening and lacerates the plant tissue by means of the barbed snout. It then pushes the tip of the mouth cone into the puncture thus made and sucks in the plant juices. Larvæ feed in a similar way, having similarly constructed mouth-parts.

RELATION OF THE BUDDING AND BLOSSOMING OF TREES TO THE FEEDING HABITS OF THRIPS.

The dark-brown adult thrips arrive on the trees in late February and early March, the period of early opening buds and first blossoms; they are common in March and April, the two months of bloom and early leaf, and all are gone from the trees by the middle of May. Only a few adults can be found after the 1st of May, and most larvæ have reached full growth by this time and have gone into the ground. Thus it is that the active feeding stages of the thrips coincide with the budding, blooming, and early leaf periods of the host trees.

FIG. 1.—The pear thrips (*Euthrips pyri*): head and prothorax from side, to show mouth-parts. Much enlarged (original).

The difference in bud formation and progress of development of various deciduous trees influence to a large extent the manner of injury which thrips inflict. Trees may be divided for the sake of convenience, in regard to the bud structure, into two groups, namely: (1) Those in which a single fruit bud produces one blossom, such as the almond, apricot, and peach; and (2) those in which a single fruit bud opens out to form a cluster of blossoms which later produces a cluster of fruits, as the prune, cherry, pear, and apple.

The relative blooming periods of the several varieties of fruit on which thrips inflict injury, as found in the Santa Clara Valley, may be noted as follows:

Group 1: Almonds, late in February; apricots and peaches, early in March.
Group 2: Prunes, middle and last of March; cherries and pears, early in April.

These periods vary from year to year and the varieties of each fruit also vary to a large degree, but the general order of blooming is suggestive. Opening buds precede full bloom by eight or ten days.

The almond, of the first group, presents an interesting study of the feeding habits of thrips. The bud development occurs during early February, early blossoms from February 5 to 16, and full bloom from February 9 to 20 and later. Thrips appear about February 25 or March 1, and it is evident that almond blossoms are

well along before enough thrips have appeared to become especially injurious. Many instances can be cited where thrips were especially numerous on almond trees, often as many as 25 or 50 inhabiting a single blossom, and yet the trees set and matured a full crop of nuts. The insects did not have an opportunity to attack the opening buds, and after blossoms were open they preferred the nectary glands on the inside of the calyx cups. They did not, apparently, relish any other parts of these particular blossoms, and the pistil, stigma, and young fruits were not attacked. Stamens were weakened, for they arise from the rim of the calyx just above the place where the insects find their enticing food, but the pollen had already ripened and had been shed. Thrips can be found as numerously on almonds as on any other variety of affected trees, but there is a large, newly exposed leaf and blossom surface, and the greatest danger period is passed before the insects arrive. For these reasons the trees are able to support many thrips without the amount or the quality of their fruit being appreciably affected.

The peach, especially the Muir and the Nicols' cling varieties, suffers as much as other fruits, but the acreage in the Santa Clara Valley is not large as compared with that of the prune, for instance; consequently the damage has not been so marked. The period of opening buds and blossoms occurs just at a time to permit of thrips entering them from their earliest development. The swelling bud pushes apart its outer winter protecting scales and thrips immediately force a way in. The insects feed on the tender, closely plaited tips of petals, which are readily killed. They force an entrance between calyx lobes and petals, feeding as they go, and soon reach and attack the very small and fragile blossom stem. This is soon destroyed. Later the blossoms which may have escaped the early injury are attacked from within, the thrips feeding on the inner flower parts. The piercing and rasping manner of feeding is very disastrous to tender plant tissue, and fatal injury can be effected by a very few movements of the powerful mouth cone with its armed tip. The writer has often examined peach trees which had but recently been attacked by thrips and found that almost every blossom would fall out from its cluster of scales when the limbs were gently tapped. Badly infested peach trees do not bloom at all.

Apricot blossoms are similar to those of the peach and are injured in the same way.

The thrips is at its worst on trees of the second group, which includes the pear, prune, cherry, and apple. These fruits bloom later, which permits the gathering of thrips in numbers before buds are at all advanced. The writer has found thrips on cherry and prune trees waiting, as it were, for the buds to open, and he has found as many as 75 individuals in a single blossom which opened prematurely early. A thrips enters a prune bud through the tip and forces

a way down the center of the cluster, feeding as it goes on the contiguous sides of the several blossom buds. Normal growth ceases immediately. The untouched outer side of each blossom bud develops for a time, but the injured inner part becomes brown and dies. This causes each flower bud to turn in toward the center, and the whole cluster eventually falls. (See Pl. I, fig. 1.) When thus injured, most blossoms do not open at all, but if they do thrips are able to enter and feed in the more vital flower parts. Only a few blossoms survive both periods of injury when thrips are very numerous. The insects attack blossom and leaf buds alike and, in fact, every part that offers new and tender plant tissue.

Pears suffer mostly during early bud development, and blossoms are nearly all dead before the clusters open.

Cherries present a more resistant growth. There is a decidedly sticky secretion on the surface of newly exposed leaves, and often wings of thrips stick fast and many are thus trapped. Cherries develop so rapidly that when buds once start, blossom clusters are able to push out, often almost unharmed, even when many thrips are present. These clusters form ideal places for oviposition, and, as will be seen later, cherry trees which may be able to resist the early injuries of feeding will suffer from the effects of ovipositing.

Thrips have displayed very decided preferences for certain flower parts. It has been mentioned that they choose the inner side of the almond calyx cup. In prunes they are partial to the tiny blossom stems and to the tips of petals and, when blossoms have opened, to the stigma and style. This last injury is especially noticeable on cherries, where the writer has many times found the stigmas and styles blackened as a result of the feeding of thrips, while the rest of the blossoms was untouched.

Injury on leaf buds and on tender foliage is almost as marked as when blossoms alone are attacked, although there can be no closely drawn line of distinction, because of the close interrelation of leaf and blossom buds. Trees that have been ravaged for three or four days can not again put forth new leaf buds and assume a natural growth for several months, and then they appear sickly for the entire year. Often they can not start anew until the thrips have actually left the trees, as the insects continue to hinder each new effort which the trees may make.

The pear thrips is known to feed on the following plants, and it is probable that this list, extensive as it is, is not complete: Almond, apple, apricot (several varieties), cherry, fig, grape, peach (Muir and Nicols' clings preferred), pear (especially Doynne du Comice and Bartlett), plum, prune, walnut (English).

The insect shows a decided preference for certain varieties of prunes, pears, and peaches, but of the other fruits all varieties seem to be attacked alike. The pear thrips has been collected from the

following indigenous plants: Blossoms of the madroña (*Arbutus menziesii*) and wild California lilac (*Ceanothus thyrsiflorus*), and foliage of poison oak (*Rhus diversiloba*). All of these plants, however, were near thrips-infested orchards, and, moreover, only a few individuals were taken from each of the plants.

FEEDING HABITS OF LARVÆ.

Thrips larvæ feed almost entirely on young, tender foliage and on the surface of fruits. They conceal themselves in terminal buds (Pl. I, fig. 2), and often, as on the cherry, they attack the underside of leaves, usually near the prominent veins. They cause the leaves to become much contorted, ragged, and full of holes (Pl. II, fig. 1). The insects seem at times to take advantage of certain tendencies in the growth of plants on which they happen to feed. For example, newly opening pear or apple leaves show a tendency to roll from the sides inward and thrips find this inner protected surface a most desirable feeding place. In such a case the upper, inner surface is destroyed, and the leaf, instead of opening out, becomes rolled up tight and eventually dies. The insect thus secures the tenderest of leaf tissue for its food, and also protection in the folded leaf. (Pl. I, fig. 2.) Thrips often cause a deadening of the leaf margin, and in such cases the leaf is forced into an abnormal, often cup-shaped, growth. This is a very characteristic injury on pear trees. (Pl. I, fig. 3.) The feeding injury of thrips larvæ on fruits, especially prunes, is in a way superficial, but it seriously impairs the appearance of the ripened fruits and greatly lessens the value of the finished product. A prune grows to be larger than a grain of wheat before the dead calyx is sloughed off. Larvæ feed under protection of this dead calyx, and as a result an abrasion of the skin, the feeding injury, is noticeable, even on very small fruits. The wound appears first as a small brown spot which enlarges and produces a scab as the fruit matures. The seriousness of what at first might seem a small surface marking is more readily appreciated when one recalls that when prunes are being cured the tough, scabby spot does not shrivel up during the process of drying as does the flesh of the prune, nor does it assume a darker color as does the prune.

FIG. 2.—Eggs of the pear thrips (*Euthrips pyri*). Highly magnified (original).

Thrips larvæ are often carried by various means from the original food plant to other hosts, being blown, for example, from a tree to grass or weeds beneath. They have no wings and can not fly back to the tree. A few crawl up again, but most larvæ adapt themselves to the new plant until fully grown, when they, too, go into the ground. Many of the common weeds have thus been found supporting larvæ, although no full-grown thrips have ever been seen feeding or deposit-

ing eggs on such plants. The insect has proved itself a strictly fruit-tree pest, and it is carried to weeds and lives on them or on other plants only by accident.

LIFE HISTORY AND HABITS.

THE EGG, THE OVIPOSITOR, AND OVIPOSITION.

The thrips egg is bean-shaped (fig. 2), light-colored, almost transparent, and is very large in proportion to the size of the abdomen when seen within the body of the adult female. It is about 0.33 mm. long by actual measurement.

The ovipositor (fig. 3) is made up of four distinct plates. Each plate is pointed, has a serrate outer edge, and is operated by powerful muscles and plates within the abdomen. The pairs on each side fit together along the inner edges with a tongue-and-groove-like structure, which in action renders possible a sliding back and forth, or sawing motion. The ovipositor is protected within a sheath in the ventral tip of the abdomen when not used, but before and during ovipositing it is lowered until almost at right angles to the body.

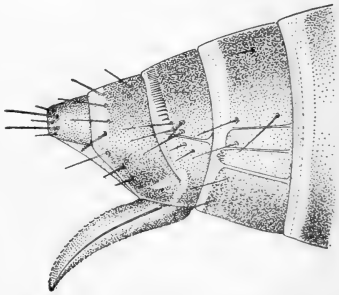


FIG. 3.—The pear thrips (*Euthrips pyri*): ovipositor and end of abdomen from side. Much enlarged (original).

Oviposition accompanies feeding. It seems necessary, indeed, that before the ovipositor can be inserted through the plant epidermis the thrips must first weaken or break an opening through this tissue with the mouth-parts. The successive operations of lacerating the plant tissue, lowering the ovipositor, placing an egg, and withdrawing the ovipositor require from four to ten minutes, and may be briefly described as follows: After making an incision with the mouth parts the insect moves forward, lowers and inserts the ovipositor, and by operating the tiny saws she makes a deep incision in the plant tissue. While the ovipositor is still deeply set in the plant, an egg is conducted through the cavity between the plates and deposited underneath the epidermis. The ovipositor is withdrawn and the egg is thus left deeply embedded within the plant. During the oviposition period one often finds a branch or a tree, or even many trees, on which almost all thrips are ovipositing at the same time.

The small, fragile, just-exposed blossoms, stems, and leaf petioles, and later the midribs and veins on the back side of the leaves, and still later even the leaf tissue itself, are the places preferred for ovipositing. A thrips always places her eggs in the tenderest of the plant's tissue. There is danger of the ovipositor getting caught if the tissue is hard. Also, it is necessary during egg development that the

surrounding tissue be flexible and moist, for the egg covering is elastic and the embryonic thrips within increases in size very noticeably before the larva issues.

There is space within the adult insect's body for only a few eggs at a time—seven or eight. A thrips probably places only a few eggs during a single day. She feeds for a time, deposits an egg, and then moves to another place, and later to still other places, and these may be all on one or scattered on several trees. The adult thus spreads her progeny from tree to tree wherever she goes. Nothing seems to hinder thrips which may be set on ovipositing. They have been observed placing eggs at all hours of the day and night and under all conditions of weather. The period of oviposition lasts for several weeks, or during practically all of the life of the adult insects. Injury from oviposition is most conspicuous on cherry trees. Operating at the base of a cluster of fruits, a few thrips will cut several incisions and place as many eggs in a single stem. This so weakens the stem that it fails to perform its usual function, and the rapidly developing cherry soon becomes yellow, and falls. Thrips seem to prefer the cherry to other varieties of fruits as a place for ovipositing during the later season, and this fruit suffers severely from ovipositing, though it may escape the first feeding injury. The result is a heavy dropping of half-grown cherries, which in badly infested regions means almost the whole crop.

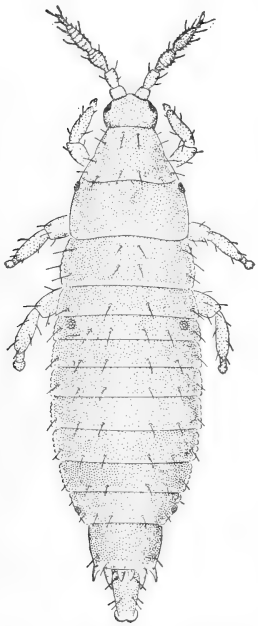


FIG. 4.—The pear thrips (*Euthrips pyri*): larva. Much enlarged (original).

Numerous leaf and blossom stems in which eggs had been placed were closely watched to determine the length of the egg stage. In many cases these stems became dry during confinement in the laboratory, and almost invariably from these no thrips issued. Eggs need moisture for their preservation and development, and young thrips must have tender and pliable tissue through which to emerge. The egg stage lasts, approximately, four days.

THE LARVA.

It is interesting to watch, with the aid of a strong lens, a young thrips issuing from the egg. The tiny incision in the stem of a blossom or leaf shows where an egg has been placed, and the enlarging egg within, causing a swelling in the plant tissue at the summit of which is the incision, indicates that the insect is about ready to emerge. The first sign of life is the appearance, pushing out from the

incision, of the head with its bright red eyes. Little by little, and swaying backward and forward, the larva forces itself out until about one-half of the body is exposed, when first the antennæ and then one by one the pairs of legs are made free from their resting position against the body. Swaying backward and forward, with legs and antennæ waving frantically about, the insect pushes out of the egg cavity almost to its full length, whereupon, leaning forward it eagerly takes a hold with its newly formed feet, and, with a final effort, pulls itself free and walks rapidly away. From four to ten minutes are required for the insect to free itself from the egg. The young insect is almost transparent and the green chlorophyll particles taken into the stomach can be seen through the body wall. Growth is rapid from the beginning.

A very decided change takes place during the second larval stage (fig. 4). In about three weeks the insect reaches a size often larger than that of the fully matured insect. It then ceases to feed, falls to the ground, and enters the ground by some crack or wormhole. It goes down from 3 to 10 inches, according to the structure and condition of the soil, the usual depth being about 4 inches. Upon reaching a secure depth, the larva hollows out for itself a tiny spherical or oblong cell or it finds an exceedingly small natural cavity and shapes this for its convenience. The completed chamber has a hard, smooth inner wall, and it is about one-twelfth of an inch long, or just a little longer than the insect itself. The insect here spends the greater portion of its life. It remains for several months a quiescent, non-food-taking larva. Later the pupal changes are undergone, and lastly the adult insect appears before it issues forth to the tree. Larvæ collected from the ground on August 28 were active, and, strange to say, green chlorophyll matter, undigested food, which had been taken into the stomach several months before, was still present in their bodies. The insects are scattered through the soil from near the trunk to several feet from the tree.

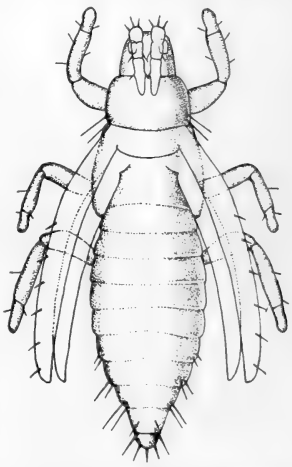


FIG. 5.—The pear thrips (*Euthrips pyri*): nymph or pupa. Much enlarged (original).

THE NYMPH OR PUPA.

The writer has not been able to determine how long the nymph stage (fig. 5) lasts, but it evidently extends over several weeks. Nymphs in all stages of development were collected during May and at intervals until the following February, but they are most common during December, January, and February. The writer has gathered

nymphs from the ground early in May, but it is difficult to explain their presence there so early in the spring. It hardly seems possible that these were the still immature forms of the previous year, for by this time all adult thrips had left the trees. These nymphs were taken along with the larvæ, which had just entered the ground, and it might seem that they were hurrying through to produce a second generation; but to the writer's certain knowledge adults of a second generation did not appear on the trees. The nymph is active at all times. Wings develop from mere buds to long sacs which project backward along the sides of the body, and eventually reach beyond the tip of the abdomen.

THE ADULT.

The adult thrips (fig. 6) remain in the pupal chamber for days, and it may even be weeks before they issue forth to take up active life. How individual thrips force their way through the several inches of earth which lies above them is still a question. They come out, it seems, only after the ground has been thoroughly softened by rains, and it is evident, too, that they depend largely on the natural openings. They can not possibly use the backwardly bent mouth cone as a means of boring or biting their way out. They have several groups of spines and certain angular edges on the sides of the abdominal segments, however, which help materially in forcing a way through the soft soil. They also possess roughened, scoop-like structures—parts of the chitinous, hoof-like shell of the feet—which undoubtedly are used for digging.

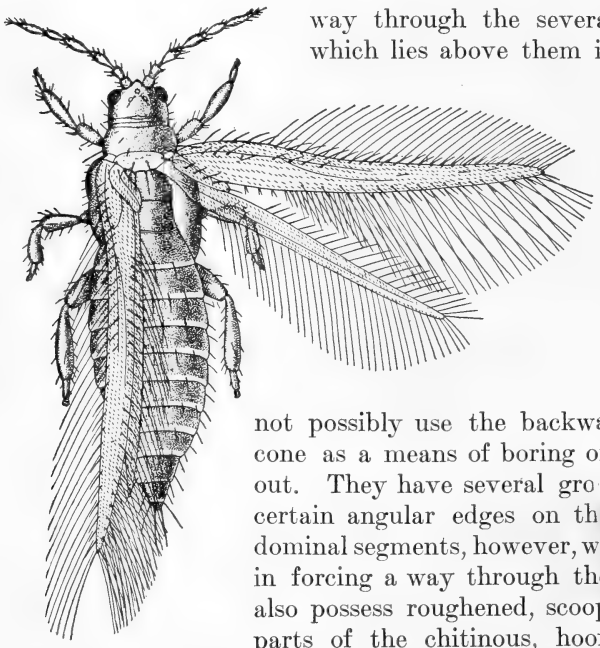


FIG. 6.—The pear thrips (*Euthrips pyri*): adult. Much enlarged (original).

Adult thrips appeared in alarming numbers in many Santa Clara Valley orchards in 1904, about February 24; in 1905 several days later, and in 1906 about March 1. They appear on the trees by millions and, it seems, all at about the same time. They feed and oviposit most actively during March and April, and by May 1 almost all have disappeared. No male individuals of the pear thrips have ever been collected; all have been females.

WORK OF THE PEAR THRIPS (EUTHRIPS PYRI DANIEL).

Fig. 1.—Imperial prune, showing buds and blossoms injured by feeding of adult thrips. Fig. 2.—Unfolding leaves of Hemskirk apricot injured by young thrips. Fig. 3.—Madeline pear, showing cup-shaped deformities of the larger and rolling of the smaller leaves, the injury caused by young thrips. (Original.)

WORK OF THE PEAR THRIPS (EUTHRIPS PYRI DANIEL).

Fig. 1.—Black Tartarian cherry blossoms killed by adult thrips and leaves injured by young thrips. Fig. 2.—Bartlett pear, showing all except very late blossoms dead from thrips and leaves injured by feeding of young thrips. (Original.)

Adults may be present in an orchard for a few days and then suddenly almost all disappear. This is explained by their habits of migration as evidenced by the following observations: In a certain pear orchard which had been kept under daily observation for a week or more thrips had been abundant in blossoms and buds until suddenly one day all seemed to have disappeared. Upon closer examination, however, they were found congregating and walking around on the larger branches. This was about 3 o'clock in the afternoon. On the following morning hardly an individual could be found in the orchard. This manner of flight seems to be distinctly migratory. Thrips often leave their places of feeding just before sunset and hover around and over and later settle back on the same trees. This mode of flight is decidedly different from the migratory one. It occurs only at evening, and the writer has never seen the pear thrips in flight during the morning or during the middle of the day.

DESCRIPTION.

Euthrips pyri Daniel.

Measurements: Head, length 0.13 mm., width 0.15 mm.; prothorax, length 0.13 mm., width 0.2 mm.; mesothorax, width 0.28 mm.; abdomen, width 0.31 mm.; total length 1.26 mm. Antennæ: 1, 33μ; 2, 45μ; 3, 63μ; 4, 54μ; 5, 33μ; 6, 66μ; 7, 9μ; 8, 12μ; total, 0.31 mm. *Color* dark brown, tarsi light brown to yellow.

Head slightly wider than long, cheeks arched, anterior margin angular, back of head transversely striate and bearing a few minute spines and a pair of very long prominent spines between posterior ocelli. *Eyes* prominent, oval in outline, black with light borders, coarsely faceted and pilose. *Ocelli* are approximate, yellow, margined inwardly with orange-brown crescents, posterior ones approximate to but not contiguous with light inner borders of eyes. *Mouth-cone* pointed, tipped with black; maxillary palpi three-segmented; labial palpi two-segmented, basal segment very short. *Antennæ* eight-segmented, about two and one-half times as long as head, uniform brown except segment 3, which is light brown; spines pale; a forked sense cone on dorsal side of segment 3, with a similar one on ventral side of segment 4.

Prothorax about as long but wider than head; a weak spine at each anterior and two large, strong ones on each posterior angle; other spines are not conspicuous. *Mesothorax* with sides evenly convex, angles rounded; metanotal plate with four spines near front edge, inner pair largest. The mesonotal and metanotal plates are faintly striate. *Legs* moderately long, uniform brown except tibiæ and tarsi, which are yellow. Spines on tip of fore and middle tibiæ weak; several strong spines on hind tibiæ. *Wings* present, extending beyond tip of abdomen, about twelve times as long as wide, pointed at tips; costa of fore wings thickly set with from twenty-nine to thirty-three quite long spines; fore vein with twelve or fifteen arranged in two groups of three and six, respectively, on basal half of wing and a few scattering ones on distal part; hind vein with fifteen or sixteen regularly placed spines; costal fringe on fore wing about twice as long as costal spines.

Abdomen subovate, tapering abruptly toward the tip from the eighth segment; longest spines on segments 9 and 10; abdomen uniform brown, connective tissue yellow.

Redescribed from many specimens, including several cotypes from Miss Daniel.

Male unknown.

Food plants: Apricots, apples, almonds, cherries, figs, grapes, pears, prunes, plums, walnuts. The insect is found mostly on deciduous fruits.

Habitat: San Francisco Bay region, California.

METHODS AND NATURAL FACTORS IN CONTROL.

The study of the life habits of the pear thrips, as already given in detail, explains why certain artificial remedies are not entirely effective, and it also suggests other methods. Adults appear suddenly in late February and early March. They enter the opening buds and feed largely in protected places, and always on newly developing plant tissue. Destruction to buds can be accomplished in a very few days—it may be in less than a week. The fully developed wings of the insect permit of active flight and widespread distribution. Oviposition, extending through several weeks, permits of a widespread and a continuous feeding period for the new brood. Eggs are safely placed within the plant tissue. Larvæ feed largely in protected places while on the tree, and then seek shelter and spend many months in the ground. An individual of the species will spend about eleven months in the ground and one on the tree, although the whole period of infestation of trees by adults and larvæ may be about three months.

SPRAYS.

Exposed thrips, both adults and larvæ, can be killed by several of the contact insecticides, but sprays have not proved successful, because the spray mixture can not be forced into the very tender buds and blossoms where the thrips are, without injuring the plants, and, besides, all of the thrips can not be reached by a single spraying. It was found in the limited experiments of 1905 that thrips could be killed over any given area, but that within a few days the infestation would be as bad as though no spraying had been done. This is accounted for by the presence of those thrips which escaped the spray and by the new individuals which had migrated into the orchard.

It would be impossible for all persons to accomplish their spraying within the few days when the thrips are arriving on the trees. Larvæ are more easily killed than adult thrips, but as they feed largely within the leaf clusters they, too, are protected. Spraying to kill larvæ would necessarily be done after the serious injury from adults had been effected. It might be possible to obtain some results by applying a poisonous spray, but the ever newly unfolding leaf surface, upon which the insects could feed and which would not be poisoned, would render this kind of spray almost useless.

CULTIVATION.

There is some ground for believing, although the evidence is not conclusive, that thorough cultivation will figure largely as a means of control for the pear thrips; but even here the treatment must cover areas of considerable extent. Thrips larvæ in the ground are mostly within reach of the plow, being usually found within 5 inches of the surface, although a few may go deeper. On uncultivated areas they

may be found within 2 or 3 inches of the surface. Thrips are entering the ground mostly during the last two weeks of March and during April, a period when the most active cultivation of the year is carried on. But the insects are very active at this time, and if they are only disturbed and not killed in the mechanical stirring of the soil they simply find a new place to hide and perhaps go a little deeper into the ground. From the following evidence, however, it is quite obvious that careful spring cultivation is helpful. A certain row of cherry trees which was badly infested with thrips during 1905 was kept under constant observation for several months because it represented various interesting conditions. The trees bordered a roadway and were for this reason cultivated only on one side. There was a strip of land perhaps 3 feet wide extending on either side of the row, which, though uncultivated, was not hardened like the roadway. In February and March, 1905, the trees in question were very badly infested, were stripped of all their fruits, and left with pale, ragged leaves. Adults were numerous. Many eggs were deposited and larvæ by thousands matured, dropped down, and entered the ground. These larvæ were actually seen entering the soil, mostly during the month of April. During April and May they were readily found in the ground several feet from the tree as well as near to its trunk. They were scattered about generally, regardless of cultivation, except that the many individuals which were unable to penetrate the hard gravel road crawled off to the side. They did not go deeper than 3 or 4 inches in the uncultivated strip near the trees, while in the well-cultivated soil they were often found 6 or 7 inches below the ground surface. They could be found easily anywhere, in April, just after entering the ground. After the spring and early summer cultivating, however, almost none could be found in the deeply cultivated soil, but they were as common as ever in the uncultivated ground. A dozen or more thrips were often collected from a small clod about an inch and a half in diameter. Small uncultivated areas may be found in almost any orchard, and it is a fact that a few square yards of ground can harbor a very large number of thrips.

Cultivation methods, however, as a means of control, can be only partially effective at best. One can not kill all of the thrips in the ground even with the most careful cultivation, and there are always men who can not or will not cultivate at the proper time. Then, too, there are areas along fences, ditches, etc., which can be cultivated only with great difficulty. What is even more important, certain kinds of soils—adobe and clays—can be cultivated only under certain conditions to be kept mellow and loose. The present manner of cultivation in the Santa Clara Valley offers almost ideal conditions for the thrips, in that the insect is left undisturbed during almost the entire period occupied by the resting stage—from June until the following February.

Thrips are in the ground all of this time, and for the most part within reach of the cultivator, but they mature and arrive on the trees in March and April, before spring cultivating is begun.

NATURAL ENEMIES.

The pear thrips is largely protected from ordinary predaceous and parasitic insects, because it spends so long a time hidden away in the ground. A successful parasite must in a way parallel the life of its host, and we have found no insect which thus follows the pear thrips. Raphidians, or snake flies, their commonest enemies in the Santa Clara Valley, feed rather on the younger forms than on the fully developed insects, and they do not appear early enough in the spring to constitute an effective check to the pest. To be competent thrips killers they would have to feed on other insects for perhaps ten months in the year and then, when thrips appear, suddenly change their diet and later, after thrips have gone into the ground, as suddenly change back again to aphides or to something else. Such feeding habits are not to be expected in a predaceous species.

FIG. 7.—A fungus which attacks the pear thrips: *a*, active fruiting stage or adult thrips; *b*, branching mycelia; *c*, forming spores. *a*, much enlarged; *b*, *c*, highly magnified. (Original.)

Ants were at one time thought to be doing much good as an enemy of the thrips. A certain orchardist brought in an ant with a thrips impaled in its jaws—the evidence complete. After a careful investigation, however, it was found that only a very small percentage of ants were actually killing thrips. Four hundred ants were examined as they descended a thrips-infested tree. Twelve of these carried something in their jaws and only 4 of these objects were thrips. Thus only 1 per cent of the ants on the tree were actually killing thrips and carrying them down. It has been a common observation among orchardists, however, that thrips are not common where ants are unusually abundant.

Spiders and mites are active enemies of thrips. In some of our breeding cages almost all of the thrips would at times be killed by some small spider or mite which had gained an entrance. The writer has observed a red mite (*Rhyncholophus* sp., determined by Mr. Nathan Banks) actively engaged in feeding on the onion thrips (*Thrips tabaci*

Lind.). Both the thrips and the mite were very common in large onion fields, covering several hundred acres. A mite would be seen to approach and grasp a thrips with its front pair of legs and, inserting its proboscis, suck out the body juices of its prey. A single mite was often observed thus to kill several thrips within a very few minutes. The writer strongly suspects that some mite preys on the younger stages of the pear thrips while it is in the ground. This would be entirely possible, and mites are commonly found in the grass and in the ground.

A fungus, presumably parasitic, has been endemic among thrips during the seasons 1905 and 1906. In its different stages it lives on both young and mature thrips, and in a way parallels the life of its host. During the spring of 1905 thrips larvæ were often observed to be thickly infesting a tree, and after these had disappeared, presumably having gone into the ground, none or but few living ones could be found. Many larvæ, too, seemed to leave the tree before they had reached full growth, and within breeding cages these larvæ were seen to die as the direct result of the parasite. Projecting from their bodies were to be seen the tiny fruiting conidiophores of the fungus. Adult thrips were seen to be attacked by another form of the parasite during the spring of 1906. The past two seasons have offered almost ideal conditions for the development of the fungus, enabling it to become quite widespread.

FIG. 8.—*a*, Resting spores of a fungus found within dead thrips larva, much enlarged; *b*, same spores, highly magnified. (Original.)

The life history of the fungus has been determined only in part. The heavy-walled resting spores, the dormant stage, are found within larvæ and adults in the ground; never, thus far, in pupæ in the ground or in individuals on the tree. Dead larvæ from the ground show that the internal body organs have all been displaced by the fungus, and in most cases the body contains only a mass of the heavy-walled spores. The transition which takes place in the formation of these spores is as yet not clear, but there seems to be a general breaking up of the fungus *hyphæ* within the thrips' body. In one well-prepared specimen there was an indistinct grouping of particles around many centers. These were presumably the forming spores, for in the next stage the formation of such spores was complete. These heavy-walled spores may be found nearly the whole year through, although they are especially abundant from May until the following February.

In the conidiophore stage on the tree the fungus hyphæ break forth in groups from between the body segments and extend out as long slender threads, which in turn branch and form numerous fruiting organs. This stage of the fungus has been taken only from adult thrips on the tree and not from the larvæ, and it has been found present almost everywhere that the pear thrips has been collected.

There is no doubt that the fungus spends a part of its life on the tree and a part in the ground, the rapidly fruiting stage among the active thrips and the heavy-walled dormant stage within the hibernating individuals in the ground; but we can only surmise how it is carried from one to the other. The bodies of the larval thrips within the ground are all absorbed by the fungus and naturally, therefore, the spores must be carried to a new host before they can germinate to any great extent. We have found adult thrips in the ground whose dead bodies contained only a few spores and others which developed some of the external mycelial growth within their cells. If this were often the case, and these individuals in the ground produced fruiting spores as they do on the trees, it would be an easy matter for healthy individuals in coming from the ground to become accidentally infested and to carry the parasite up to the tree where, because of the gregarious habits of the insect, it would spread rapidly.

The fungus grows readily in the nutrient agar under ordinary conditions and seems to retain its virulence and can be transferred from cultures to the living thrips. The fungus may prove to be a check for the pear thrips, but its effectiveness is uncertain because it is so subject to climatic conditions.

U. S. D. A., B. E. Bul. 68, Part II. D. F. I. I., July 6, 1907.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE SPRING CANKER-WORM.

(*Paleacrita vernata* Peck.)

By A. L. Quaintance,

In Charge of Deciduous Fruit Insect Investigations.

INTRODUCTION.

Two species of canker-worms in the United States, the spring canker-worm (*Paleacrita vernata* Peck) and the fall canker-worm (*Alsophila pometaria* Harr.), are often very troublesome pests in apple orchards, infesting also the elm, cherry, and, to a less degree, a few other trees. These insects, though widely distributed, usually occur in injurious numbers quite locally, infesting often but one or two orchards in a neighborhood where conditions have been favorable for their development. The females of both species are wingless, hence their dissemination is very slow. The insects are doubtless distributed mostly on nursery stock in the egg stage, or locally the larvæ and moths may cling to clothing of persons, or may be distributed by teams visiting the infested orchards.

Old orchards which have been in sod or have not been cultivated for many years and which are not sprayed with arsenicals furnish ideal conditions for the multiplication of canker-worms when the latter are once established. Frequently such orchards are defoliated each spring, with the result that the injury to the trees prevents the formation of fruit buds, and after a few years of such injury the trees will begin to die. While certain weather conditions and the natural enemies of canker-worms may often greatly reduce the number of these insects, energetic steps on the part of the orchardist are usually necessary to insure the complete destruction of the pests and to permit the trees to resume their normal fruit production. In the great majority of cases, if not in all, canker-worms are practically limited to orchards which are neglected as to spraying and cultivation, either practice usually serving to keep them so reduced in numbers that their injuries are inconsequential.

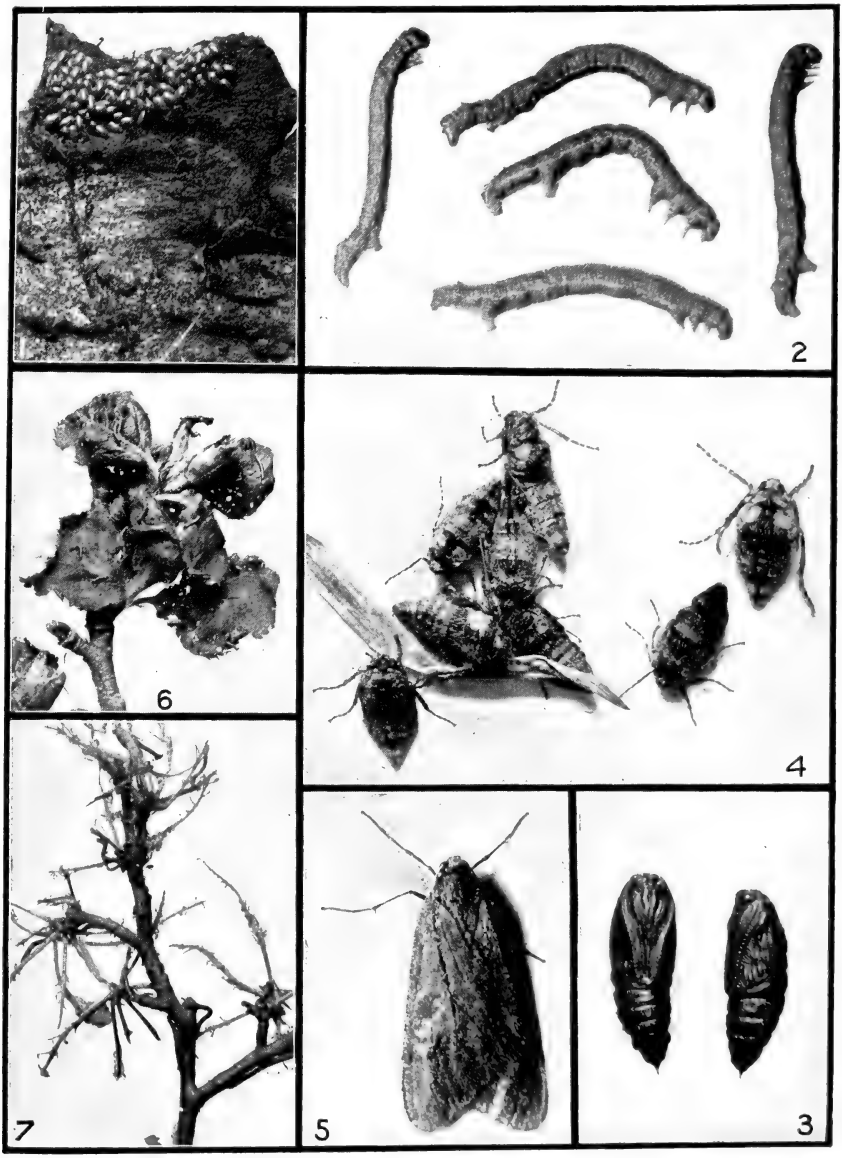
Complaints of both fall and spring canker-worms are frequently received by the Bureau of Entomology. Correspondents often report that they are unable to protect their trees by the use of arsenicals, and the opinion has at times been expressed that these insects can not be destroyed by arsenical sprays. While it has often been stated in the literature on canker-worms that they are more resistant to poisons than many other species of insects, yet there is no doubt that they may be readily killed by thorough use of poisons. In most cases the poor results from spraying are evidently due to failure to make thorough applications of the spray, the large size of the trees and the unfamiliarity of the orchardist with spraying operations often contributing to this end.

In the present brief article the life history and habits of the spring canker-worm are given, together with results of practical work in its control. The life history and habits of the fall canker-worm practically parallel those of the spring species, except that the great majority of the moths of the former species emerge and oviposit in the fall. The operations of spraying and plowing herein discussed will be equally effective in its control.

LIFE HISTORY AND HABITS.

There is but one generation of canker-worms each year. After obtaining their growth on the trees in the spring, the larvæ enter the soil to a depth of from 2 to 5 inches, and after making an earthen cell transform to pupæ (see Pl. III, fig. 3), in which condition they remain until the following spring. Early in the spring, or even during warm spells in winter, the pupæ transform to moths, which make their escape from the soil and go to the trees. The males are winged, as shown in Plate III, figure 5, but the females are destitute of wings, as illustrated in Plate III, figure 4. In ovipositing the females climb the trees and place their eggs in irregular masses under loose bark scales, in cracks in the bark, in crotches of limbs, etc., as shown in Plate III, figure 1, which illustrates an egg mass which was placed on the underside of a bark scale. The number of eggs in an individual mass varies greatly. Females taken presumably before oviposition had begun deposited eggs in confinement, the number to a mass varying from 17 to 119, with an average for 12 masses of 47.

An individual egg is elongate-elliptical in outline, somewhat resembling a hen's egg in miniature. The average dimensions of ten recently deposited eggs were found to be 0.69 by 0.42 mm. When first deposited the surface is shining, pearly white, but in the course of a few hours the egg takes on a yellowish-green color, in certain lights showing a golden, greenish, or purplish iridescence. As the embryo approaches maturity it becomes very evident and lies curled around just within the shell, its cephalic and caudal ends together, the egg-



STAGES AND WORK OF SPRING CANKER-WORM (PALEACRITA VERNATA PECK).

Fig. 1.—Egg mass on bark scale. Fig. 2.—The larvæ or canker-worms. Fig. 3.—Pupæ. Fig. 4.—Female moths. Fig. 5.—Male moth. Fig. 6.—Work of canker-worms on apple leaves when small. Fig. 7.—Later work of the larvæ, only the midribs of leaves being left. Figs. 1–5, considerably enlarged; figs. 6, 7, reduced. (Original.)

shell becoming more or less concave centrally. Shortly before hatching the eggs become quite dark, due to the color of the larva within. Eggs secured from females in confinement on the nights of March 8, 10, and 12, and kept under out-of-door conditions in the insectary yard at the Department of Agriculture, Washington, D. C., were hatching April 10, 11, and 14, respectively, giving for this stage a fairly uniform period of thirty-two to thirty-three days. The effect of warm weather upon the development of the embryo may be judged from the fact that eggs kept in the insectary at a temperature of 65 to 70° F. hatched in about eleven and one-half days.

When just hatched the spring canker-worm is quite small, measuring but 1.25 to 1.5 mm. in length, varying with the extension of the body. The head is about 0.25 mm. wide, which slightly exceeds the width of body across thoracic segments. The head and shield are shining black, and the body above dark olive-green, with a distinct central longitudinal white stripe centered with narrow interrupted lines of the same color as the body. Along each side is a wide irregular white stripe, including the spiracles and adjacent tubercles. Below, the body is dark yellowish or brownish in color. The thoracic legs are stout and dusky exteriorly. There is a single pair of prolegs on the sixth abdominal segment and a pair of anal prolegs.

The larvæ come from the eggs about the time the leaves of the apple are pushing out, and the latter are at once attacked. At first only small holes are eaten through the leaves, but later, as the larvæ grow, the entire leaf substance save the midrib is devoured. (See Pl. III, figs. 6, 7.)

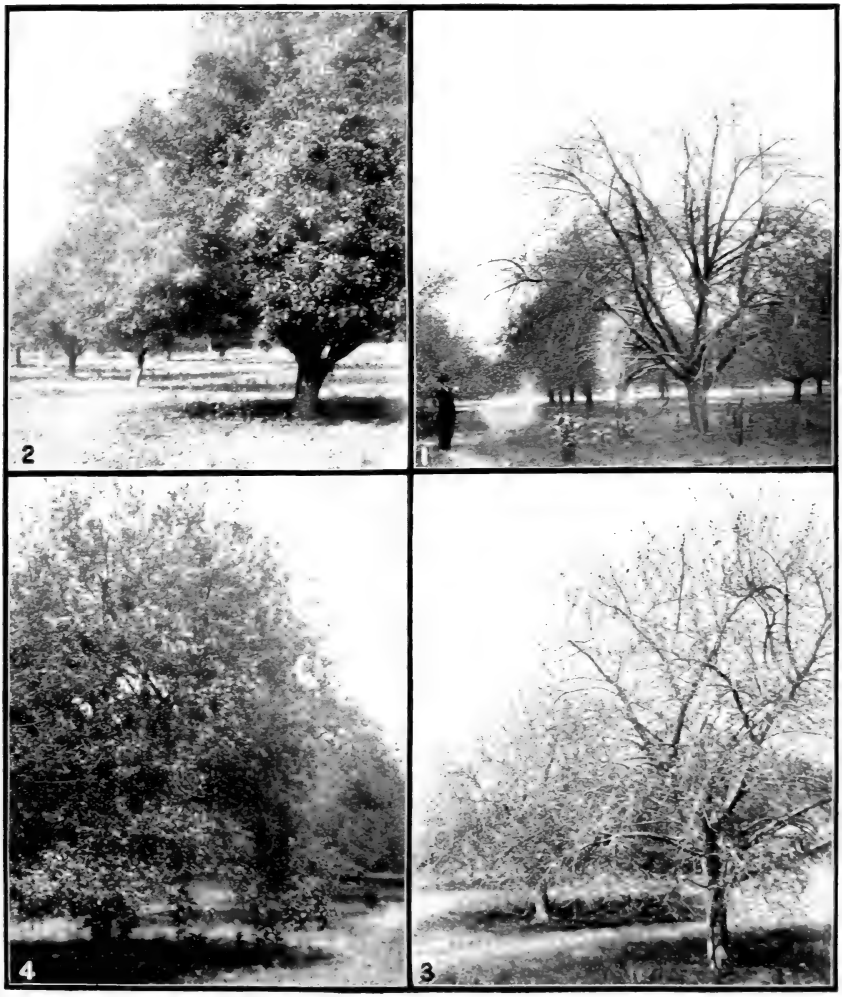
After three or four weeks of feeding, the time varying much with the temperature, the larvæ have become full grown. They then measure from 18 to 23 mm. (0.7 to 0.9 inch) in length. Considerable color variation is likely to occur, some specimens being ash-gray, green, or yellow, but the predominating color is dark greenish olive or blackish. There are two pale narrow lines down the back, centered with a broader dark stripe and a whitish stripe along each side. (See Pl. III, fig. 2.) The larva of this species is readily distinguished from that of the fall canker-worm by the fact that the former has but two pairs of prolegs, while the latter has three, the first pair, however, on the fifth abdominal segment, being more or less reduced.

Newly hatched larvæ placed on apple trees under a large wire cage in the insectary yard April 12, 1905, had matured and were entering the ground for pupation by May 8, and by May 11 all had disappeared from the trees. This gives twenty-seven to thirty days for the larval existence. The egg and larval stages together require some two months, and the remainder of the year, except the time spent in the adult condition before ovipositing, is passed in the pupal stage in the soil. As has been stated, the insect pupates from about

2 to 5 inches below the surface of the ground and may be readily destroyed by thorough plowing and cultivation during the summer and fall.

DEMONSTRATION WORK IN CANKER-WORM CONTROL.

For several years the spring canker-worm has been quite troublesome in a few old orchards in northern Virginia and very little headway had been made by the owners of the orchards in its control. In the spring of 1905 Dr. John S. Lupton, of Winchester, Va., desired the assistance of the Bureau of Entomology in freeing from this pest his large orchard of 30-year-old Newton pippin trees, which had been defoliated to a greater or less extent for three or four seasons. The orchard had been in sod for years and no recent spraying had been done for the codling moth. Under these conditions the canker-worms had been able to multiply with practically no interference and had become exceedingly abundant, 50 per cent of the trees being practically defoliated and the others more or less so. A plan of treatment was submitted to Doctor Lupton, which was carried out by him under the writer's supervision. This treatment consisted in a thorough spraying of the orchard with Paris green at the rate of 1 pound to 75 gallons of water (plenty of lime being added to lessen danger of injury to the foliage), the thorough plowing of the orchard during the early summer, and its subsequent cultivation during that season. Only one application of poison was made, and not until much later than was desirable, the larvæ being already from one-half to three-fourths grown, many trees having been practically defoliated. Nevertheless, the treatment checked further defoliation and within two to three days the larvæ had largely disappeared. That the majority were poisoned was evident, since upon later examinations pupæ were exceedingly scarce, even under trees from which the leaves had been almost stripped. During early August the orchard was thoroughly plowed, special pains being taken to break up the soil under the trees. Late in the fall the worst infested portion of the orchard was again plowed, and at right angles to the direction followed in the first plowing. The rest was plowed early the following spring, the whole being prepared for corn, which later was planted, receiving necessary cultivation during 1906. As was quite evident in the spring of 1906, the thorough spraying with Paris green and plowing of the orchard had destroyed the great majority of the insects. In the early spring of 1906 bands of a sticky preparation placed around the trunks of trees which had been practically defoliated in 1905 caught not more than two dozen specimens of adults in all, and larvæ were very difficult to find later. That the absence of the insects in this orchard is to be attributed solely to the spraying and plowing and not to unfavorable weather conditions or the influence of parasitic



TREES DEFOLIATED BY SPRING CANKER-WORMS AND EFFECTS OF TREATMENTS.

Fig. 1.—Defoliated trees in Lupton orchard. Fig. 2.—The same trees a year later. Fig. 3.—Defoliated trees in the Purcell orchard. Fig. 4.—An adjacent row of trees protected by two applications of arsenate of lead. (Original.

and predaceous enemies is evident from the fact that in a near-by orchard, untreated, the insects were excessively numerous, completely defoliating the trees during the spring of 1906. Figure 1, Plate IV, is from a photograph of trees in the worst infested portion of the Lupton orchard in 1905, and shows the injury that had been done before the application of the Paris green spray. The condition of these same trees, but looking in another direction, on June 9, 1906, is shown in figure 2.

During the spring of 1906 spraying work against canker-worms was also carried out in another orchard near Winchester consisting of 30 acres of 35-year-old Baldwin trees. This orchard also had been entirely neglected as to plowing and spraying for many years past, and for some years most of the trees had been completely defoliated by the spring canker-worm, some of them and portions of others being dead. Arrangements were made to spray a portion of the orchard, though it was not considered practicable by the owner to have the ground plowed. Arsenate of lead was used as a poison and applied at the rate of 3 and 5 pounds per 50 gallons of water for the first and second applications, respectively. At the time of the first application the leaves were well out, being from three-fourths of an inch to an inch in diameter. The canker-worms had almost all hatched, very many being in the second stage, and were literally swarming over the trees. The second application was made May 5, most of the larvæ at this time being from one-half to three-fourths grown, the untreated trees being already nearly bare of leaves. The treated trees, while showing some injury from the larvæ, especially in the higher parts, were in almost full foliage, though subject to infestation from adjacent trees. The second application largely protected the trees from further injury, and there is no doubt that if the entire orchard had been treated the insects would have been practically exterminated. Figure 3, Plate IV, shows the defoliated condition of untreated trees June 9, after the larvæ had all disappeared, and the condition of sprayed trees in an adjacent row is shown in figure 4 on the same plate.

RECOMMENDATIONS.

Orchardists having canker-worms to contend with may confidently expect to practically eradicate them in the course of one or two seasons by following the methods above described, namely, thoroughly spraying the trees with a strong arsenical and thoroughly plowing the ground during the summer. If Paris green is used, this should be applied at the rate of 1 pound for each 100 gallons of water, and unless used in Bordeaux mixture there should always be added the milk of lime made from slaking 4 or 5 pounds of good stone lime. Arsenate of lead may be used at the rate of 6 to 10 pounds to 100

gallons of water or Bordeaux mixture, and because of the strength at which it may be used without injury to foliage and its excellent sticking qualities it is to be preferred to other arsenicals for canker-worms. At least two applications of the poisoned spray should be made; the first as the fruit buds are exposed, or just as the foliage is pushing out, but before the blossoms open, and the second in eight to ten days, or at once after the blossoms have fallen. In bearing orchards the second treatment is the principal one for the codling moth, and if the poison be used in Bordeaux mixture the two applications of this combined insecticide and fungicide will largely protect the trees and fruit from canker-worms, the codling moth, and other leaf-feeding insects, and will lessen apple scab.

While it may often appear impracticable to spray some orchards on account of the height of the trees, most orchards may be plowed and cultivated, and this work should certainly form a part of the plan of canker-worm eradication.

Another important method of protecting high orchard and other trees which it is impracticable to spray is the employment of special protectors, such as bands of cotton, or sticky substances. These are placed around the trunk of the tree near the base, and are used to prevent the ascent of the wingless females to deposit their eggs, or the ascent of any larvæ from eggs deposited below the bands or which have fallen from the trees. Sticky substances, such as printer's ink, tar, bird lime, and certain proprietary preparations, are best. On account of the danger of injury to the trees, these are best applied on strips of paper 5 or 6 inches wide and of sufficient length to go around the tree. The loose bark should first be scraped from the trunk where the band is to be applied, and if a light band of cotton batting be first fastened where the paper band is to be placed this will effectually prevent the insects working up beneath the sticky paper band. Cotton batting may also be used, the trunk being encircled with a strip 4 or 5 inches wide. This is tied with a string at the lower edge and the band then turned downward. This will be effective so long as it remains fluffy, but usually requires renewal after heavy rains. Whatever form of protector is used must be applied quite early in the spring, at least six or eight weeks before the apple buds are due to burst, as the moths come out very early, sometimes even during warm spells in the winter.

The methods of control given above are equally applicable to the fall canker-worm, except that in the use of bands to prevent the ascent of moths these must be applied in early fall, since the moths of this species oviposit mostly during that season.

U. S. D. A., B. E. Bul. 68, Part. III. D. F. I. I., October 15, 1907.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE TRUMPET LEAF-MINER OF THE APPLE.

(*Tischeria malifoliella* Clemens.)

By A. L. Quaintance,
In Charge of Deciduous Fruit Insect Investigations.

During 1905 this species became unusually abundant in the District of Columbia and in localities in adjacent States. Specimens of mined apple leaves were received from Afton, Va., Newark and Woodside, Del., Cheltenham, Pa., and Vermont. Judging from the condition of the leaves sent, the insect in these several places was much less abundant, however, than in the immediate vicinity of Washington. During 1906 the insect was again exceedingly abundant in the environs of Washington, was the subject of further complaint from Delaware, and was received from Connecticut.

HISTORY.

This species was described in 1860 by Clemens in the Proceedings of the Philadelphia Academy of Sciences, Volume XII, page 208, from material presumably from Pennsylvania. Interesting observations concerning its food plants are presented by Chambers in the Canadian Entomologist, Volume III (1871), page 208; Volume V (1873), page 50, and Volume VI (1874), page 150. Additional notes are given by him in the Cincinnati Quarterly Journal of Science, Volume II (1875), page 3; in Bulletin U. S. Geological and Geographical Survey, Volume IV (1878), page 107, "Tineina and their Food Plants," and in Psyche, Volume III (1889), page 68. Messrs. Frey and Boll, in Stettiner Entomologische Zeitung, Volume XXXIV, page 222, note its occurrence in Germany on apple imported from this country. The insect has been occasionally mentioned by Lintner in the reports of the New York State Entomologist and elsewhere, and is the subject of an article with bibliography in his Eleventh Report. Dr. E. A. Brunn, in the Second Report of the Entomological Department of Cornell University (1882), in a

paper on the Tineidæ infesting the apple trees at Ithaca, N. Y., gives an account of the insect with figures of moth, larva, and mines in apple leaf. A more extended account is given by Dr. C. M. Weed in the Fifteenth Report of the Illinois State Entomologist (1889), pages 45–50; and it is mentioned by Lugger in Minnesota Experiment Station Bulletin 61 (1898), page 316, and later (1903), by Washburn, in Minnesota Bulletin 84, page 66. In Bulletin 180 of the Michigan Experiment Station (1900), page 125, and Special Bulletin 24 of the same institution (1904), page 22, the species is the subject of short illustrated articles by Pettit; and it is also discussed by Lowe in Bulletin No. 180 of the New York Agricultural Experiment Station (1900), page 134. In 1906 brief mention is made by C. P. Close of the occurrence of this species in central Delaware (Bul. 73, Delaware College Agric. Exp. Station, p. 18), where it is said to have been increasing for several years past.

The above includes the important references to this species so far as the writer has been able to determine.[a]

DESCRIPTIVE.

The mine.—The mines occur exclusively on the upper surface of leaves, beginning at the point of deposition of the egg as a narrow, often curved line, gradually or suddenly enlarging in isolated and typical examples, and finally having the outline of a trumpet or mussel shell (see Pl. V). Completed mines vary much in shape and size, but will average, perhaps, in the more typical examples one-half inch long by one-fourth inch wide. There is considerable irregularity in the feeding habits of the larvæ, and blotch mines are often produced, the narrow linear portion being frequently more or less obliterated. In many mines crescent-shaped patches of white cross the linear portion, extending often well into the body of the mine. Unless held to the light the mine is scarcely noticeable from the lower surface of apple leaf, but above the blistered epidermis varies in color from whitish to dark brown, and the spotted appearance of badly infested leaves is noticeable some distance from the trees. Injury is confined principally to the palisade layer of cells immediately below the epidermis of the upper surface of the leaf. The position of the mine on the leaf is quite variable, but it does not usually cross the larger veinlets, extending more or less parallel with them.

The egg.—The eggs of *Tischeria malifoliella* are regularly elliptical in outline, somewhat convex centrally, but flattened around the margin, which area is more or less wrinkled. When first laid they

[a] Since this article was prepared this species has been well treated by Mr. C. D. Jarvis, in Bulletin 45 of the Storrs, Connecticut, agricultural experiment station.

are greenish yellow in color and somewhat translucent. In some lights they are irridescent, as are the empty egg shells. One or two days previous to hatching they become comparatively conspicuous, the embryo being central and the whitish margin showing plainly against the dark color of the leaf. The empty shells are white and mark the beginning of the mine. The average size (based on measurements of five eggs) is 0.34 mm. by 0.54 mm. The eggs are attached closely to the leaf, usually in furrows along a veinlet, but occur more or less promiscuously. This stage has not previously been described.

The larva.—The larva (fig. 9, *c*) upon hatching measures about 0.7 mm. in length. The head is brownish, the rest of the body whitish, except cervical and anal shields, which are dusky. Full-grown larvæ will average 5 mm. in length by 1 mm. in width across the third thoracic segment. The head is about 0.5 mm. wide, retractile, bilobed, brownish or even black in color. The general color of the body is light green, except cervical and anal shields, which are brownish. The body is flat, with the segments very distinct, and tapering caudad from the second or third segment, the last three segments rounder and narrower than the preceding. Thoracic segments with three long setæ on each side; succeeding segments with two setæ on each side varying considerably in length; at caudal end there are numerous shorter curved setæ. Thoracic legs absent. Abdominal and anal legs marked by five pairs of crochets (see fig. 9, *c*, *d*).

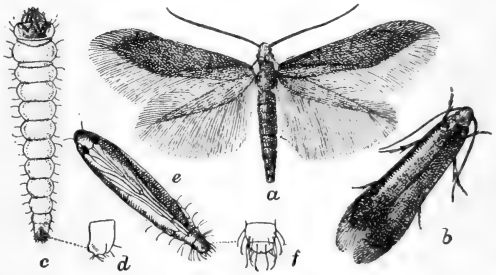


FIG. 9.—Trumpet leaf-miner of the apple (*Tischeria malifoliella*): Adult, larva, pupa, details.

The pupa.—The pupa is rather variable in size, the average of five being 3.35 mm. by 0.95 mm. The color when first formed is rather uniformly pea green, later becoming much darker, varying with age. The general color of the thoracic region and head is dark brown to blackish. The abdomen is dark green, yellowish caudad; the caudal margin of the rather distinct segments is brown. Leg and wing sheaths free; tip of third pair of legs reaching to cephalic border of third segment from last. The antennal sheaths reach the cephalic margin of the fifth segment from last. The spiracles are on slight conical elevations, and on each side of abdomen, ventrad of spiracles, is a row of long slender setæ, a pair to each segment. Cremaster of two stout short projections, slightly curved at tip. Head obtusely

rounded, without horn-like processes, but with a pair of slender setæ. This stage has not hitherto been described, the description given by Weed being evidently that of the pupa of some other species. (See fig. 9, *e*, *f*.)

The adult or moth.—The description given by Clemens is as follows: "The head and antennæ shining, dark brown, face ocherous. Fore wings uniform, shining, dark brown with a purplish tinge, slightly dusted with pale ocherous; cilia of the general hue. Hind wings dark gray; cilia with a rufous tinge." (See fig. 9, *a*, *b*.)

FOOD PLANTS.

In his original description Clemens gives the food plant as apple. Chambers states that he bred it from leaves of different species of haw (Cratægus), sweet-scented crab (*Pyrus coronaria*), blackberry (*Rubus villosus*), and raspberry (*Rubus occidentalis*), and adds that it probably mines other species of Rosaceæ. Later Clemens says that this species, as well as certain others, feeds indifferently on leaves of Cratægus, Prunus, and Malus.

In 1873 Messrs. Frey and Boll described *Tischeria ænea*, bred from *Rubus villosus*, and *Tischeria roseticola* from *Rosa carolina*. In the Cincinnati Quarterly Journal of Science Chambers adds th berry (*Rubus canadensis*) to the food plants of *Tischeria mali* and does not consider *T. ænea* of Frey and Boll, from blackbe tinct from *T. malifoliella;* he regards as belonging to this species the specimens bred from all the species of Rubus, Cratægus, and Pyrus. He also doubts the distinctness of *T. roseticola*. However, in a later publication, "Tineina and Their Food Plants," Mr. Clemens recognizes the two species of Frey and Boll above cited, and as food plants of *T. malifoliella* gives Cratægus, *Pyrus coronaria*, and *Pyrus malus*, omitting as food plants species of Prunus, Rubus, and Rosa, assigning the two latter as food plants of *ænea* and *roseticola*, respectively. The distinctness of the three species was again recognized by Chambers in his Index to the Tineina of the United States and Canada, and more recently by Doctor Dyar in his "List of N. A. Lepidoptera."[a]

Finally Mr. Pettit notes serious damage to blackberries from *T. malifoliella* at the South Haven substation in Michigan, and states that the insects seem to breed in the neighboring apple trees and come to the blackberries from them. However, in the absence of definite breeding work and the critical comparison of adults thus secured, it will be best to follow the evident conclusions of Chambers and Dyar, and limit the food plants of *T. malifoliella* to species of Cratægus and Pyrus. During the present season (1907) the insect

[a] Bul. 52, U. S. Nat. Museum, 1902.

WORK OF THE TRUMPET LEAF-MINER OF THE APPLE (TISCHERIA MALIFOLIELLA): LARVAL MINES IN APPLE LEAF.

was never found on blackberry, though growing in abundance near infested apple trees.

SEASONAL HISTORY.

But little of a definite character has been recorded concerning the seasonal history of this species. Clemens states that "when pupation begins the leaf is thrown into a fold, which is carpeted with silk, and the pupa lies within it. This state begins about the latter part of September, and the imago appears early in May." Brunn, who studied the species at Ithaca, N. Y., says, referring to the mines, "Within these clean and comfortable quarters the larva passes the winter." The observations of Weed, reported in "Injurious and Other Insects of Illinois" (1886), agree entirely with those of Brunn; and Lintner, writing in 1895, says it hibernates within the leaf in its larval stage. Pettit, in 1900, states that "The larvæ are said to change to the pupal condition during September, and to remain in that condition until the following May," and again, in 1904, he says, "The pupal stage is passed in the mines of the leaves, necessarily on the ground in the winter time." Observations of Lowe in 1900 at Geneva, N. Y., agree with those of Brunn and Weed, though on October 29 a larva was found evidently about to pupate.

Until 1900 this species was evidently considered single brooded, though no definite observations seem to have been made on this point. During that year Pettit reported for Michigan that full-grown larvæ were found about the middle of July and again September 16, indicating at least two generations of larvæ. August 16, 1905, in Niagara County, N. Y., the writer found numerous empty mines with protruded pupa cases, and a single live pupa in a mine. Young larvæ from eight to ten days old were fairly common, indicating a second generation for that section.

The abundance of the insects in the vicinity of Washington during the past two years has permitted some observations on this point. In 1905 the insect was first noticed, May 30, on an isolated apple tree near the writer's home in Kalorama Heights, D. C., and this tree has been kept under observation during the seasons of 1905 and 1906. On May 30, 1905, when first seen, the first generation of larvæ was maturing, one pupa being found, and by June 18 the great majority of larvæ had pupated, and quite 25 per cent of the moths had already emerged. The first generation of larvæ was quite abundant, almost every leaf having 8 to 10 mines. Practically all pupæ had yielded moths by June 30, and the leaves were peppered with eggs, many of which had already hatched, the larvæ being yet quite small, in linear mines. By July 27 the second generation of larvæ had mostly pupated and many moths were out and ovipositing.

The number of mines per leaf at this time averaged from 15 to 18. By August 4 pupæ had largely yielded moths, and eggs were again very abundant, a few having already hatched. By August 26 another generation of moths had developed and their eggs were in an advanced condition of development and many had already hatched. September 10 larvæ of this, the fourth generation, were of various sizes, from quite small to full-grown, but no pupæ could be found. The leaves, although practically covered with the mines on their upper surfaces, were still hanging on the trees, and there was but little evidence of serious injury having been done. By October 30 quite 50 per cent of the foliage was on the ground and those leaves remaining on the trees were more or less rolled in from the edges. This premature falling of the foliage was undoubtedly due to the work of the leaf-miner, and this seems to have been its principal injury. At this time the larvæ were full-grown and had lined their mines with a dense lining of silvery-white silk preparatory to hibernation. Leaves picked from the ground contained from 6 to 15 larvæ per leaf. Leaves examined December 6 showed no change of condition, no pupæ whatever being found, and this condition was also found to obtain on January 21. March 12 a quantity of leaves were collected from the ground, and at this time fully 90 per cent of the larvæ had transformed to pupæ, though this stage had but recently been entered, as indicated by the bright-green color. On April 22, at which time the foliage of the apple was just pushing out, only pupæ could be found, and some of these were quite dark in color, the inclosed moth evidently being nearly developed and ready to escape. The formation of pupæ as just mentioned is perhaps to be regarded as abnormally early, since the weather about this time was unusually warm. This belief is strengthened by the fact that in infested apple leaves kept in a breeding cage out of doors in the insectary yard the insects were all in the larval condition, except one pupa, on April 5, the moths mostly emerging the latter part of that month. By May 7 eggs were very abundant on the foliage of the apple tree under observation, as many as 12 being counted on a single leaf, but on some leaves none at all were to be seen. At this date no larvæ had yet hatched, though many eggs were in an advanced stage of development, the embryo being readily seen within the delicate shell when examined with a hand lens. By June 24 larvæ from these eggs had mostly matured and had entered the pupal stage, though a few full-grown larvæ were still to be found. The time of maturing of the first generation in 1906, therefore, agrees closely with this period in 1905.

Length of life cycle.—Eggs deposited during the night of July 31 were very generally hatching on the morning of August 8. The larva leaves the egg by eating directly through the lower surface at one end into the leaf beneath, at once beginning its mine, and is thus

at no time exposed. The act of leaving the egg is very deliberate, and may occupy ten or twelve hours before the body is completely out of the shell and into the mine. Feeding alternates with resting, the larva often working backwards out of the mine into the egg-shell, where it may rest for half an hour or more. The mines are at first but little wider than the width of the insect and are lined with silk from the start. Progress at first is slow, the larva proceeding about twice its length during the twenty-four hours following the breaking of the eggshell. After a few days, however, it feeds much more vigorously and soon widens the mine in the course of its feeding.

Of the larvæ which hatched the morning of August 8, 12 out of the 15 under observation pupated during the night of August 25, this stage therefore lasting approximately eighteen days; and the moths from these pupæ mostly emerged by the morning of September 2, one emerging the morning of August 30, making for the life cycle about thirty-three days. Moths kept in confinement without food lived for about two days. According to Chambers, the larvæ molt five times, and there are no marked differences either in color or structure between the larvæ at different stages of growth.

DISTRIBUTION.

The trumpet leaf-miner is evidently a native species, its original food plants probably being species of Cratægus and wild Pyrus. It has been recorded from New York, Texas, Illinois, and Michigan. The material on which Clemens based his description was probably from Pennsylvania, and the observations of Chambers made in Kentucky indicate its occurrence in that State. Records of this Bureau show it to occur in South Carolina, Virginia, Delaware, Pennsylvania, Connecticut, Rhode Island, Vermont, Massachusetts, Missouri, Arkansas, and Nebraska, and at Ottawa, Canada.

PARASITES.

This miner is freely parasitized. At Ithaca, Dr. Brunn bred from it *Sympiesis lithocolletidis* How. and *Astichus tischeriæ* How. The former species has been bred from this insect at Champaign, Ill., by Weed, and *Elasmus pullatus* Howard is doubtfully recorded from this species from Missouri. At different times during the season of 1905, at Washington, D. C., infested apple leaves were placed in jars, and the following species were secured, some of which probably are secondary parasites: *Urogaster tischeriæ* Ashm., *Sympiesis nigrofemora* Ashm., *Horismenus popenoei* Ashm., *Closterocerus trifasciatus* Westw., *Eulophus* n. sp., *Zagrammosoma multilineata* Ashm., and a variety of this species. A species near Phygadeuon was reared, and one near, if not identical with, *Cirrospilus flavicinctus* Riley.

TREATMENT.

When excessively abundant, as has been the case in several localities during the past two or three years, the injury done by the larvæ in the leaves will cause many of these to fall prematurely, interfering with the proper development of the fruit and the health of the tree, and its control, therefore, becomes a matter of importance. This can perhaps best be accomplished by plowing the orchard in the spring, covering as much as possible all fallen leaves and trash, as in the former the larvæ pass the winter, and it is practically certain that the moths will not be able to make their escape from the soil. This work should be done not later than the blooming period of the trees, to insure covering up the infested leaves before any early-emerging moths escape. As this method of control involves no extra labor not requisite in proper orchard treatment, this species, which has but recently attracted attention as a pest of the apple orchards, is not to be regarded as a serious pest of the apple in the sense that it will require independent treatment.

After the insect has become established in orchards, and its immediate control appears necessary, a thorough spraying of infested trees with 12 or 15 per cent kerosene emulsion made in the usual way would no doubt result in the destruction of the larvæ and pupæ in the mines in the leaves, and possibly also of the eggs scattered over the foliage. Such work, however, should be done on clear, bright days, to lessen as much as possible danger of injury to the foliage from the spray. Tests of a kerosene lime emulsion alone, and with Bordeaux mixture and Paris green, have been reported by Prof. C. P. Close, formerly of the Delaware College Agricultural Experiment Station, in Bulletin 73 of that institution. In the experience of Professor Close, applications in early August of 10 and 15 per cent kerosene lime emulsions, with Bordeaux mixture and Paris green, were quite effective in killing larvæ and pupæ in the leaves. Applications of kerosene lime emulsions in September on the succeeding brood were not so successful in killing the insects, and the apple foliage was injured, possibly on account of its weakened condition following the work of the miners.

U. S. D. A., B. E. Bul. 68, Part IV. D. F. I. I., October 17, 1907.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE LESSER PEACH BORER.

(*Synanthedon pictipes* G. & R.)

By A. A. Girault.
Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

Until recently the only lepidopterous borer of the peach known to be common and injurious in the East was the peach borer (*Sanninoidea exitiosa* Say), an insect well known to entomologists and fruit growers alike. About ten years ago—in 1896—however, another somewhat similar borer, the subject of this paper, now called the lesser peach borer, was mentioned by Webster as "the peach borer," and again, four years later, Smith recorded it as being sometimes found on the peach in New Jersey, though apparently it was not considered a pest of any importance. It was with some surprise that, in the investigation of the peach borer by this Bureau during the past two years, this insect was discovered to be very abundant on peach in Maryland and Georgia, and also to a less extent in western New York and adjacent portions of Canada, occurring especially in the trunks of old or diseased trees. At first the larva was confused with that of the peach borer, but dissimilarities in its habits soon led to its recognition, which was confirmed upon rearing adults. Aside from its being a practically unrecognized enemy of the peach, the insect is of interest from the fact that it has heretofore evidently been more or less confused with the true peach borer, to which the larva bears great resemblance in general appearance. In subsequent pages there is given as complete an account of the species as is possible at this date.

HISTORY.

Up to the year 1906 the species under consideration had not been treated as an insect of special economic importance. Previous to this time it had been known mostly as occurring on the plum and

cherry, and it had not been sufficiently abundant to cause more than occasional record of the fact in the literature of economic entomology. For instance, it is not mentioned in the Catalogue of the Exhibit of Economic Entomology at the Lewis and Clark Centennial Exposition, Portland, Oreg., 1905, given in Bulletin No. 53 of this Bureau. It has been listed several times, however, as occurring on plums and cherries, and in the following cases had been mentioned especially in respect to its injury to these plants: Kellicott reported serious injury, in some instances, to plums in New York State in 1881, but Smith, nine years later (1890),[a] stated that it was rare in New Jersey. In 1892 Kellicott reported serious injury to cherries in Ohio. In 1899 Lugger thought the insect was increasing in Minnesota. Finally, in 1906, Quaintance reported it as very abundant in Georgia, causing material injury to peach trees.

ORIGINAL DESCRIPTION; SCIENTIFIC NAME.

The insect was first described as new to science in 1868 by Grote and Robinson, from adults captured in the "Atlantic district (Penna.)." It was given the specific name *pictipes* and placed in the genus Ægeria of Fabricius. In 1881 it was redescribed as new by Henry Edwards under the name of *Ægeria inusitata*, from specimens obtained in the White Mountains, New Hampshire, and at Andover, Mass. Twelve years later Beutenmüller (1893) established *inusitata* Hy. Edwards, as a synonym of *pictipes*. In the meantime Smith (1890) had removed the species *pictipes* to the genus Sesia of Fabricius, which removal was accepted later by Beutenmüller (1896, 1897) and Dyar (1902). Soon afterwards Holland (1903), finding that the name Sesia had been restricted to a genus of the Sphingidæ by Fabricius, applied to the genus Hübner's proposed name, Synanthedon, which seems to be the proper course in this case (p. 385). The insect's scientific name, therefore, is *Synanthedon pictipes* (Grote and Robinson).

COMMON NAMES.

Owing to the fact that the lesser peach borer feeds in the larval stage on a variety of trees it has become known by local or common names, depending on its most common or most important food plant in particular localities. It was first found on plum, and hence was first called, by Bailey in 1879, the plum-tree borer, which has since been the name oftenest applied to it. In 1896, as previously mentioned, Webster referred to it incidentally as "the peach borer;" and in 1906 it was designated by Starnes as "the wild-cherry borer." In the same year, however, because of its increasing abundance on the

[a] Dates in parentheses refer to the bibliography at the end of this paper.

peach and apparent preference for this tree over others hitherto chosen, Quintance proposed for it the name of the lesser peach borer, in distinction from the better known peach borer *Sanninoidea exitiosa* Say. This name seems preferable to any of the others, and more logical, because the peach is the most important food plant which it attacks at the present time.

FOOD PLANTS; CHARACTER AND EXTENT OF INJURY.

It has already been indicated that the lesser peach borer has more than one food plant, a habit usual with the members of the family to which it belongs. Bailey, in 1879, first found it on the cultivated plum. Two years later, in 1881, Kellicott found it attacking old plum trees at Buffalo, N. Y., and also wild cherries (*Prunus serotinus* and *P. pennsylvanicus*). In 1891 the same author stated that, in addition to its favorite food plant, it also attacked wild black and red cherries at Columbus, Ohio, and very probably would be found on the cultivated cherry. Again the following year (1892) he briefly states that it attacks both cultivated and wild cherry in the same locality of Ohio. In 1893 Webster reared the insect from the black-knot fungus, *Plowrightia morbosa*, on cherry and plum. Beutenmüller (1896), three years later, gave two additional food plants, juneberry (*Amelanchier canadensis*) and the beach plum (*Prunus maritima*). During the same year Webster (1896) recorded it on peach. Beutenmüller (1897) then added chestnut, and in 1899 Lugger added wild plum, making the following known food plants to date: Cultivated and wild plums and cherries, black-knot fungus on plum and cherry, juneberry, beach plum, chestnut, and peach.

Recent records of this Bureau show that this borer has a decided preference for peach. For instance, in Georgia where large plum and peach orchards are grown side by side, an examination of each kind of tree showed that it was common on the latter and scarce on the former. We have been unable to find it numerous on wild plum and cherry in that State, nor have additional food plants been found. In Maryland we have found the larva in a knotty growth on peach some 5 feet above the ground. Mr. W. F. Fiske, of this Bureau, reared adults from girdled chestnut trees (*Castanea dentata*), at Tryon, N. C., May 28, 1904.

The insect is evidently increasing on peach, and at present in certain localities causes costly and, in the case of individual trees, fatal injury. Bailey (1879) records a fatal attack on a plum tree in New York; and as an example of such concentrated attacks on individual trees in orchards mention may be made of the case of a nearly girdled 3-year-old Greensboro peach tree in Georgia, from the slender

trunk of which were taken 14 pupæ, 1 larva in cocoon, and 28 larvæ of various sizes.

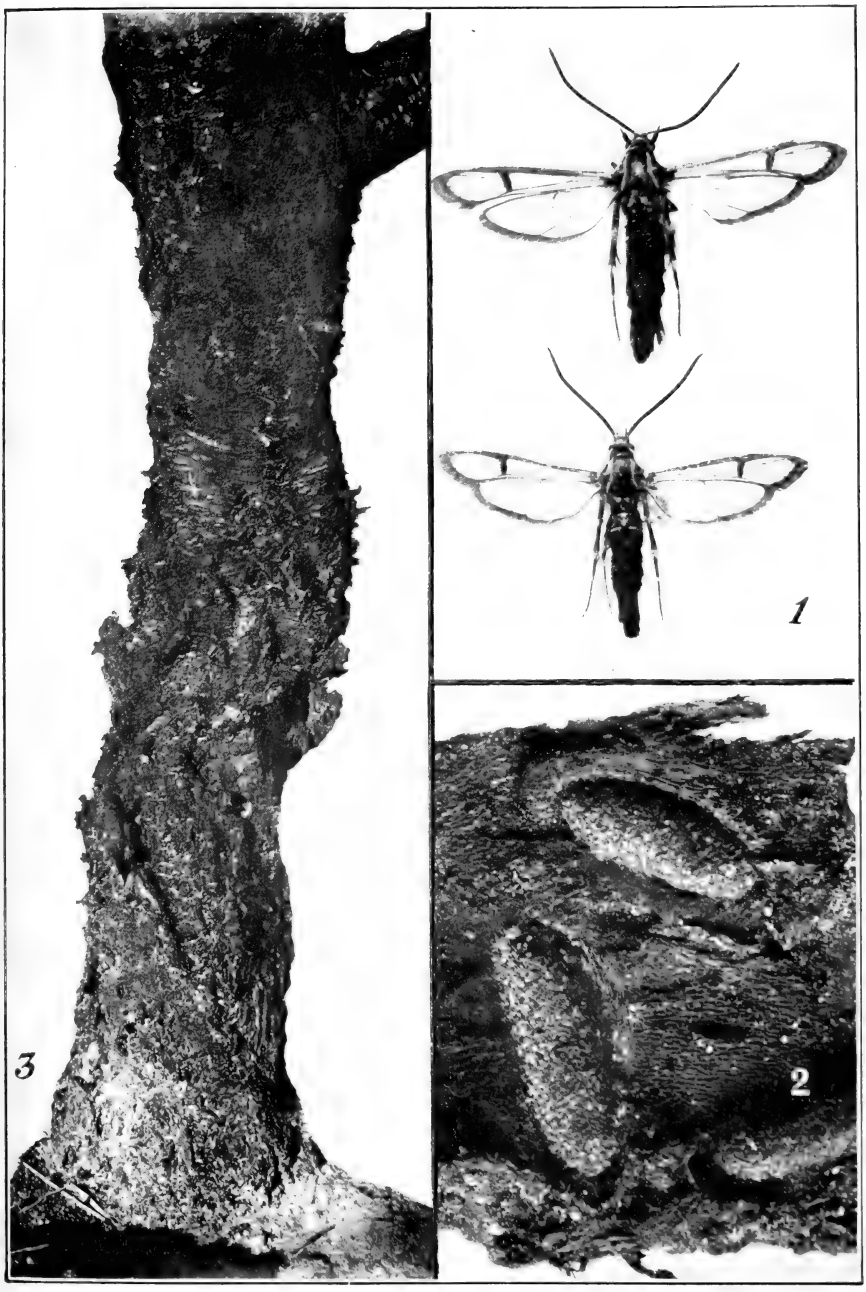
The attack of this insect is somewhat similar to that of the peach borer, but differs in many respects. Apparently it attacks none but injured trees, where the bark has been injured in various ways, and it is therefore usually found in old trees where this condition is more likely to occur (see Pl. VI, fig. 3). Further, the larvæ occur upon the trunk as a rule, make more irregular and longer burrows, and generally follow the outlines of wounds or along the edges of the cracked bark. They may be found, however, at or slightly below the surface of the soil and above the crotch or fork of the tree in the larger branches. The larvæ feed on the soft tissues of the living bark, and an infested tree exudes a considerable amount of gum from the area in which they are working. In some of the Georgia and Maryland peach orchards groups of old, scarred trees have been found with their trunks literally honeycombed by the channels of these larvæ, and this is likely to be the condition in any neglected orchard in which the trees have reached some size. An average of two larvæ to the tree was found in 14-year-old trees in Georgia in 1906, but occasionally individual trees were discovered harboring as many as 40 or 50 specimens of the insect in various stages.

DISTRIBUTION.

The lesser peach borer is rather widely distributed in the United States, to which it is native. In his List of North American Lepidoptera, Dyar (1902) simply gives "U. S.," denoting general distribution. Beutenmüller (1901), in his monograph of the Sesiidæ of America North of Mexico, gives from Canada to Florida and Texas, westward to the Pacific. It has been recorded from the following States: New York and adjacent portions of Canada, Pennsylvania, New Hampshire, Massachusetts, Illinois, New Jersey, Ohio, California, North Carolina, Minnesota, Maryland, District of Columbia, Virginia, and Georgia. It has been recorded as common and locally injurious in New York State and Ohio. The records of this Bureau (Quaintance, 1906) report it common in Maryland, western New York and circumjacent territory, and in Georgia, where it is especially abundant. It is known to occur on peach in New Jersey, Ohio, New York, Virginia, Georgia, District of Columbia, and Maryland.

LITERATURE.

The literature of this insect is not extensive. Bailey (1879) gives the only account of its life history yet published, and his description



LESSER PEACH BORER (SYNANTHEDON PICTIPES).

Fig. 1, Male and female moths (male above); fig. 2, cocoons as exposed by removing bark from trunk of peach tree; fig. 3, trunk of 10-year-old peach tree badly infested with the larvæ. Figs. 1 and 2, enlarged twice; fig. 3, much reduced. (Figs. 2 and 3, original; fig. 1, from Quaintance.)

of the character of injury is especially good. From time to time it has been treated systematically and figured, or listed, and for such treatment reference should be made to the bibliography given at the close of this article.

LIFE HISTORY AND HABITS.

The winter is passed in various stages of larval development under the bark of the trunks of the trees. Upon the approach of warm weather, and during warm spells in the winter in the South, the larvæ feed, and as they reach full growth construct cocoons and pupate (in March and April in Georgia and Maryland, respectively). About a month afterwards the moths begin to emerge and mate, and the females at once commence to deposit their eggs along the tree trunks. On account of the unequal development of the hibernating larvæ, the period of pupation and subsequent emergence of the adults lasts for several months. The eggs hatch after about ten days, and the young larvæ enter the bark through crevices and begin to feed. In Georgia, in the course of several months, these larvæ reach full growth and pupate, and the resulting moths establish another generation in the early fall, which hibernates as larvæ. The two generations are considerably mixed.

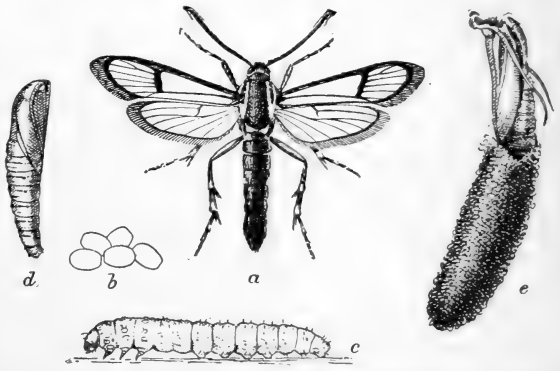


FIG. 10.—The lesser peach borer (*Synanthedon pictipes*): *a*, Adult; *b*, outline of eggs; *c*, larva; *d*, pupa; *e*, cocoon and pupal skin. (Original.)

The seasonal history of this borer is therefore very unlike that of the peach borer. It differs markedly in the fact of a partial second generation, and the further fact of early spring pupation.

The egg.—The egg (fig. 10, *b*) is a small, compressed, elliptical-oval, reddish-brown object, similar in general to the eggs of the peach borer and other members of the family Ægeriidæ. It harmonizes in color with the bark of the trees upon which it is deposited, and on this account is difficult to find. Seen from the side the anterior end is truncate, but viewed from in front it is found to be concave, the micropyle situated in the center of the concavity. The upper side of the egg, as seen when in position on a tree, is com-

pressed and concave, the hollow being oval and following the outline of the margins; the bottom side or base is flat. The surface is rough and sculptured into irregular polygons with from three to six sides. The eggs are adhesive, hard, visible to the naked eye, but minute, measuring 0.63 by 0.38 mm., and are deposited singly. They differ in aspect from those of the peach borer, and also are usually lighter in color and not as large and stout. They are rather more difficult to find in nature.

At present the length of the period of incubation is not well known. Mr. Quaintance records it as $7\frac{1}{2}$ days in the month of September, latitude of Washington, D. C. Upon hatching, the little larva cuts its way through the anterior end of the egg, leaving quite a large exit hole in the egg shell, which retains its shape and place until it weathers off.

The eggs were first observed in nature by Bailey (1879); he found a cluster of them on the under surface of loosened plum bark, about 6 inches above the roots. Usually, however, they are deposited singly along the trunk of the tree, being placed in crevices, openings, or roughened places. Sometimes a few are placed on the ground or high up in the tree on twigs or leaves, but the majority are deposited on the main trunk of the trees. The number deposited by a single female is unknown. Moths kept in confinement refuse to mate, and the female deposits few eggs or none at all. To determine the number resort is therefore made to dissection. Mr. Quaintance dissected two fertile females after death, and found 305 perfect eggs in one and 296 in the other, in addition to numbers of small undeveloped ones. Each moth had deposited a few eggs before dying, which were included in the count. Dissection of the ovaries of a sterile moth yielded but 58 perfect eggs, but there were present many undeveloped ones. Until more dissections are made the evidence on this point remains inconclusive.

The larva.—When the larva hatches it is very small, and especially hard to detect with the naked eye because of its dull white color. It is an ordinary caterpillar, bearing the usual setæ and number of prolegs, and in its earlier stages is almost indistinguishable from the young larvæ of the peach borer. However, after molting once or twice it acquires a different aspect, which together with a more pinkish and translucent color makes it somewhat more distinct. Throughout all its life it remains about the same color—various shades of creamy white—and lives concealed under the bark. The following is a description of a full-grown larva, or instar VI:

Length, 20.5 mm., average. Greatest width, 3.4 mm. Width of head, 1.94 mm., average. Normal for the family: Body soiled cream color, immaculate, with the usual more or less generalized characters. Head yellowish brown,

darker at base of clypeus and on labrum and mandibles, and blackish at the lower outer angles of the paraclypeal pieces, edges of clypeus, and tips of the mandibles; pale at vertical triangle, outer edges of paraclypeal pieces, gular surfaces, epistoma, palpi, and antennæ, the last two somewhat darkened; mandibles broad and short, indistinctly five-toothed, the two inner teeth mere serrations, the third tooth short, truncate, and broad, one-half shorter than the second, which is shorter and broader than the first, which is also obtuse; cutting edge of mandible oblique; two setæ present, arising together from middle of inner edge. Clypeus long, acutely triangular, its lateral margins sinuate, not distinctly truncate at basal corners, which are impressed and bear two setæ, one caudad of the other; paraclypeal pieces long, narrowed centrally, including the clypeus; on the inner side of each paraclypeal piece near the posterior end is a slight depression from which arises a small seta, near the apex of the clypeus. Ocelli 6, weak, pale, the first four in a quadrangle, each with a distinct lateral pigment spot; the fifth more cephalad, ventro-laterad of antenna, also with pigmentation; the sixth smaller, caudo-laterad of the fifth, and without pigmentation; the group protected by setæ.

Cervical shield pale yellow, bearing twelve setæ, in two groups of three each on each side of meson, all separated, and the caudal one of the first group separated by a suture; laterad of the shield, cephalad of spiracle, a group of three from a calloused tubercle, of which the cephalic two are much the longer; directly laterad a group of two from a fleshy elongate tubercle, the caudal seta the larger; between these setigerous tubercles, caudad and opposite the spiracle, is a narrow nonsetigerous tubercle, much narrower than the second setigerous one (one next to the fore leg); spiracle oval, brownish; "vii" and "viii" small, on the venter (?) and base of fore leg. On segments II and III, i in the dorsal region consisting of two setæ, the laterad larger; ii the same, slightly advanced, dorso-lateral aspect; iii single, minute, caudad between ii and iv, nearer the latter; iv single, large, in a line laterad with iii, advanced slightly beyond i, and in the stigmatal line; v small, its setæ larger than iii, single, much advanced, cephalo-laterad of iv; vi some distance caudo-laterad of v, about in a line transversely with i, single, equal to iv, above base of leg; all in the second annulet. A calloused spot behind iii, and a smaller one above vi, some distance caudad of v. Segment IV, single, i cephalad, small, in first annulet; ii larger, caudo-laterad of i; i and ii from dorsal aspect, forming a trapezoid; iii some distance from i in a transverse line, equal to ii, apparently in the first annulet, just above spiracle; iv and v combined just below the spiracle, the seta of v larger; vi caudad, nearer to vii than to iv and v; vii consisting of two setæ in the ventro-lateral line, and viii of one seta in the ventral region, minute; a minute calloused spot behind iv and v. Segment V, the same, vii consisting of three setæ, one of which may be obsolete. Segments VI, VII, VIII, and IX, the same; vii, three setæ on cephalo-lateral aspect at the base of proleg; viii, minute and single, inner side base of proleg; the intermediate seta of vii longest. On segment X, ii caudad of i, vii consisting of two setæ, the inner the larger, vi nearer to vii. Segment XI, i and ii closer, the latter also closer together transversely, iii cephalo-mesad of the spiracle; iv small, against, and cephalad of the spiracle; vii a single seta. Segment XII, i apparently absent; ii, iii, and iv in a transverse line, iii and iv combined; v minute, between iv and vi, slightly cephalo-laterad of iv; vi large, cephalad; vii and viii single. Anal shield subobsolete, pale, bearing four large setæ on each side, minutely maculate. Segment XIII, four minute tubercles across the venter (vii and viii ?), in front of each proleg, and just below the shield, a line of five on each side of the segment, of unequal size.

Spiracle oval, inconspicuous, brown; that of segment XI larger, somewhat obliqued, and farther dorsad. The crotchets of the legs are variable in number, often unsymmetrical, and generally arranged as follows:

Proleg.	*Anterior row.*	*Posterior row.*
1.	14–18	12–14
2.	14–17	12–15
3.	14	12
4.	12	11
Anal.	8	0

For the first four prolegs, the crotchets vary from 11 to 18 in number; for the anal proleg they vary from 8 to 9. There are generally more present than in *Sanninoidea exitiosa* (see fig. 10, *c*).

As compared technically with the full-grown larva of the peach borer, the latter is 34 mm. long, 6 mm. in greatest width, with the width of the head at least 3 mm. The head of *S. exitiosa* is slightly darker in color, with a distinct, though variable, subtriangular pale area on each epicranial lobe, where they join below the vertical triangle; the mandible is relatively more robust, darker at the teeth, four of the latter distinct, the second tooth longest and more slender, the outer next in length, the third one-third shorter than the second, and obtusely rounded, the fourth a distinct tooth, but abruptly shorter, approaching the fifth, which is a mere serration; the two mandibular setæ are larger. The lateral margins of the clypeus are straight, each one changing angle at its basal third, making the clypeus shaped like △, instead of triangular; the basal corners of it are truncate. The parclypeal pieces are generally straight, but curving basally to follow the margins of the clypeus; they are uniform in width. The first two ocelli and the sixth are practically pigmentless. The shields are darker yellowish. The arrangement of the tubercles is the same, but they are relatively larger, as are also the accessory warts and the setæ. There is a less number of crotchets in the prolegs, ranging from 8 to 16, and in the anal proleg from 5 to 8.

Though these technical differences exist, they can not be recognized in all points without considerable study, and an examination of a series of larvæ. The most conspicuous difference is the greater size of the larva of *Sanninoidea exitiosa* and its different aspect.

During the course of its growth the larva molts several times, each casting of the skin marking the end of a separate period of larval development called an instar. There is no direct evidence by rearing to show how many of these instars there are, but it has been shown that the heads of lepidopterous larvæ are of certain limited sizes in each instar, and therefore by measurements of a large series of the heads of these larvæ, the conclusion is reached that there are six, as shown in Table I. The larva molts five times. The length of the separate instars has not been determined, but Mr. Quaintance records a little over seven months as the length of the larval stage for an individual reared on peach out of doors, from September to the following April, in the latitude of Washington, D. C.

TABLE I.—*Measurements of the head of the larva of Synanthedon pictipes in each of the six instars.*

	I.	II.	III.	IV.	V.	VI.
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Average size	0.27	0.55	0.86	1.18	1.53	1.94
Range	(*a*)	(*b*)	0.72–0.95	1.02–1.25	1.36–1.70	1.84–2.64
Difference			0.23	0.23	0.34	0.80

[a] Constant. [b] Not obtained.

After hatching the young larva enters the tree by the way of a crevice and soon begins to feed on the soft living tissues. It grows rather rapidly and makes an irregular burrow between the living bark and wood of the tree. This channel, in time, becomes filled with semiliquid gummy exudations and the reddish frass of the larva. Where the larva enters there is left a small pile of fine reddish wood dust. It is partial to wounds or diseased areas on the trunk, but, as formerly stated, may occur anywhere on the tree, from the crown of the root to the larger branches, and thus may be found feeding side by side with the peach borer.

In confinement the larvæ will feed readily and grow on fresh pieces of peach bark; Mr. Quaintance has fed one for several days on peach leaves. When young, they are able to suspend themselves with silk, and Bailey (1879) has observed them "drinking" moisture.

After the larva attains full growth and is ready to pupate, if some distance from the edge of a wound or crack, it cuts a hole through, or nearly through, the outer bark, and constructs a cocoon under this in a suitable cavity, so that its anterior end is against the opening. If it is near the edge of ruptured bark, which is more commonly the case, the cocoon is made just within the boundary of the wounded area, so that the pupa easily pushes out when ready to issue as an adult. In old peach trees with cracked bark the cocoons are usually found in this position.

The cocoon is constructed of pieces of bark chewed into fine bits, frass, and silk secreted by the larva, and is light yellowish brown in color and soft to the touch. An old cocoon, however, is dark in color, and hard and brittle. The size of the cocoon varies, but it is always several millimeters longer than the pupa which it incloses.

The pupa.—The larva, having formed a cocoon and inclosed itself within, waits several days and then pupates. The pupa (fig. 10, *d*) is brownish yellow in color, darker at the edges of the segments, sutures, head and wing covers, spindle-shaped, and is broadest at the first abdominal segment. It has all the characters normal to its family. The setæ are sparse and minute. The spines on the first abdominal segment are very weak; in the female there is but a single

row of these spines after the fifth abdominal segment, and in the male after the 6th abdominal segment. The secondary sexual characters are therefore distinct (Beutenmüller, 1901, p. 231). The cremaster consists of eight stout spines surrounding the anal end. Structurally the pupa is similar to that of the peach borer, but easily distinguished from it by its much smaller size and lighter color, by the smaller and lighter cocoons, and by the more finely granulated structure of the latter. The pupa varies considerably in length, being from 10–17 mm., averaging about 14 mm.

Just after formation the pupa is nearly white, gradually turning darker and becoming its normal color after some hours. As the instar approaches its close, it turns darker and darker, gradually assuming the color of the inclosed moth, becoming steel blue-black a day or so before emergence. Emergence, however, may be delayed several days after the assumption of this color. In the cocoon the pupa is naturally covered with more or less moisture.

The duration of the pupal instar varies according to season and latitude. At Myrtle, Ga., and vicinity records of actual instars obtained during 1906, from pupæ first formed, in the late winter and early spring, showed a maximum period of 32 days, and a minimum period, toward the end of April, of 20 days. In the latitude of Washington, D. C., records obtained in 1905 for first pupæ, formed in April, the adults emerging early in May, gave the actual pupal instar from 20 to 30 days. By the middle of May in the same latitude the period had decreased to from 15½ to 17 days, where it remained for the rest of the month. Mr. W. F. Fiske records the actual pupal instar at Tryon, N. C., as being about 26 days during May, 1904. These records do not include the several days spent in the cocoon as a larva, which must be added.

Immediately preceding the final ecdysis the pupa becomes restless and somewhat swollen, and, by aid of the rows of spines with which it is armed, rather quickly works its way through the anterior end of the cocoon up to about its fourth or fifth abdominal segment. The moth emerges while the pupa is in this position, projecting for more than half its length from the cocoon. (See fig. 10, *e*.)

The adult.—Moths of the lesser peach borer (fig. 10, *a*, and Pl. VI, fig. 1) resemble in general others of the family Ægeriidæ and more particularly the males of the peach borer. They may be distinguished most easily from the latter by the fact of their bearing but two yellow bands on the abdomen, on the second and fourth segments, respectively, the band on the fourth segment sometimes not entirely encircling it; whereas the male of the peach borer has a yellow band on the posterior margin of each of the abdominal segments, some of which may be more or less obsolete. The males of the latter are also larger than the moths of the former, but again agree in having a general

hymenopteriform aspect, but flying in the bright sunlight the two species are easily recognized after a little practice in observing them. The sexes of the lesser peach borer are quite similar, but may be distinguished by one or two minor secondary characters, such as the simple antennæ of the female and the more robust abdomen and straight anal tuft. Probably the most available secondary character, however, is found in the frenulum, which in the female consists of two closely applied, long, and slender spines, while in the male it is single and slightly shorter. This character is concealed by the front wings.

The adults emerge from the pupæ in the morning hours, generally between 7.30 and 9.30, the males issuing slightly earlier than the females. They are more likely to issue on clear days, being somewhat retarded by cloudy or inclement weather. At the time of ecdysis the pupa, which is projecting from the cocoon as described, commences peristalsis-like movements of the abdominal segments, which after several seconds cause the pupal integument to part rapidly along the meson of the thorax and the sclerites of the head and wings. Almost simultaneously with this parting of the pupal integument, the moth begins to move forward and glides out, the forelegs holding to the nearest object to prevent it from falling. The actual emergence requires but a few seconds. At this time the moth is perfect but for folded wings, and can move with a peculiar jerky, gliding motion when it falls to the ground or is disturbed, but otherwise it prefers to remain motionless or to crawl to a convenient place. During the unfolding of the wings, when the moth is weak and delicate, it is probably in the most critical stage of its existence. If it falls, it is likely to injure the soft wings and become crippled, in which case it will almost certainly die a few hours later. The slightest injury at this period appears to be fatal directly or indirectly. The wings begin to swell at once and slowly expand, becoming normal after about 8 to 10 minutes. After expansion, however, they are still weak and unfit for use for at least another half hour.

As soon as ready for flight, the female moves to a convenient place and, taking position, begins to attract the males by elevating the end of the abdomen and extending the ovipositor horizontally from it. No perceptible odor is present. In badly infested orchards the males will begin to arrive after 3 or 4 minutes, or earlier, and soon a swarm of a dozen or more will be humming around the female. The sexes unite suddenly; the male grasps the female with the claspers, and then turning assumes the position normal to the Lepidoptera. Copulation may last a variable time. Mr. J. H. Beattie, then connected with this Bureau, observed a pair remain in copula for 65 minutes on August 16, 1905, at noon, and an observation made in the late summer of 1906 gave 58 minutes. In case the weather is unfavorable

or no males appear, the females will continue to await them for several days, during the time from about 10 a. m. to 3 p. m.

Oviposition commences soon after copulation and continues throughout the life of the female. On warm sunny days it may begin as early as 8 o'clock in the morning, in the South, and continue at intervals through the day until as late as 4.30 p. m. On very windy or stormy days the female is inactive, hiding in the grass in the orchard for shelter, and on cloudy days she is less active than on clear ones. During the period of oviposition she flies very rapidly, and is hardly discernible until she alights on the trunk of a tree; she then moves slowly over the bark and feels with the end of the yellowish ovipositor for a rough place or crevice, where she usually places an egg. Ovipositing females are exceedingly difficult to follow with the eye, and in this respect they differ markedly from the comparatively sluggish and more conspicuous females of the peach borer. Further, they are apparently more careful in placing eggs, always selecting a place which will make it easier for the larva to get into the bark, though enough observations have not been made on this to justify a positive statement.

In flight both sexes resemble wasps and make a distinct buzzing sound. The males are seldom seen. The moths have never been observed to feed, except on moisture, and in confinement show no marked attraction to sweetened water. Meager observations made on adults kept in confinement indicate that they probably do not live longer than a week.

SEASONAL HISTORY.

GENERATIONS.

The number of generations occurring with an insect of this kind is especially difficult to determine because of the nature of its habits. In Georgia some attempt has been made by this Bureau during the past two years to obtain accurate knowledge on this point by keeping periodical record of specimens taken from a number of peach trees during the entire breeding season. So far, however, the data obtained do not warrant a definite or positive statement concerning the actual number occurring. They are, however, sufficient to indicate more or less clearly that a partial second generation during the breeding season does occur.

As previously stated, throughout the winter the larvæ may be found in all instars, excepting perhaps the first, so that recently hatched and nearly full-grown specimens are present, the former indicating late fall, the latter, late summer, oviposition. As soon as spring begins to open the old larvæ commence to pupate, emerging a month later as adults; the young larvæ feed and grow rapidly, pupating in their turn, and producing a continuous supply of moths. The moths from the hibernating larvæ produce another mixed generation

of larvæ which reach full growth and begin to pupate and emerge as moths in the late summer and early fall. In turn these early fall adults oviposit, producing a mixed generation of larvæ throughout the fall of the year; these pass the winter and mature the following spring. Hence two cycles of this insect are clearly indicated during a calendar year in the latitude of Georgia. A clearer conception of the probable occurrence of these two generations may be obtained by consulting Table II.

TABLE II.—*Generations of the lesser peach borer at Myrtle, Ga., 1905–6.*

Generation No.	Larvæ.	Pupæ.	Moths out.	Approximate length of cycle.
1. Winter.....	Sept. 10–May	Mar. 1–May 20 (Apr.).	Apr. 1–June 20 (May).	7½ months.
2. Summer	Apr. 10–Aug. 1 (May and June).	July 20–Oct. 15 (Sept.).	Aug. 15–Nov. 20 (Sept. and Oct.).	4½ months.

In Georgia, in 1906, the first pupa of what may be called the winter generation was found on February 27, and by the middle of March they were common. A month later, in April, the adults of that generation were common, continuing so throughout May and part of June. By the latter part of May the pupæ became scarce, showing that by this date the winter generation was practically over. From that date on we conclude that the larvæ then present in the trees were practically all of the next, or summer, generation. By the last week in July pupæ were again found in numbers, and continued to increase well into September, when adults of the summer generation were observed ovipositing. The winter generation, therefore, became established mainly in the latter part of August and during the whole of September, and the larvæ from eggs deposited then had ample time to obtain at least two months' steady growth before being disturbed by cold weather. The foregoing statement is based on series of specimens collected weekly throughout the entire season of 1906, from February to November, at Myrtle, Ga., by Mr. A. H. Rosenfeld and the author, combined with records obtained by Mr. James H. Beattie during the investigations in 1905 at Fort Valley, Ga.

Observations made in the vicinity of Odenton, Md., and Washington, D. C., show that the pupæ were present in the spring as early as the first week in April and that adults issued from these during the first half of May. The pupæ continued present as late as May 8, but thereafter we have no records. Mr. Fred Johnson, of this Bureau, records seeing adults at North East, Pa., on May 29; and at Niagara, Canada, June 23, 1905, Mr. Quaintance found larvæ nearly or quite full grown, and pupæ and adults were present. Bailey (1879) found the moths as early as May 25, in 1879, at Buffalo, N. Y., and made a general statement to the effect that they issue during June and July. Kellicott (1881) reports the same months for New York and Smith (1900) for New Jersey, and similar statements

have been made by the various authors. For northern latitudes we are unable at present to form any definite conception as to the number of generations.

LENGTH OF THE LIFE CYCLE.

The length of the life cycle or developmental period of a generation of the lesser peach borer, based on field observations, has already been given in connection with Table II. The life cycle of the summer generation was approximately 4½ months, and of the winter generation 7½ months. Fortunately Mr. Quaintance has succeeded in actually rearing a single specimen of this insect through its entire cycle, in the grounds of the Insectary of this Bureau. On September 5, 1905, he placed 8 recently hatched larvæ in small artificial wounds made 3 feet from the ground on the trunk of a peach tree. Each larva was placed in a separate wound and the whole then protected by a wrapping of paper. By October 1, not quite a month later, 5 of the larvæ were found in their respective wounds and had grown remarkably, being from a half to five-eighths of an inch in length (13 to 16 mm.). On the 24th of the same month, or just over a month and a half after hatching, the five larvæ were still alive and were either about to molt or had just done so; three of them measured 13 mm., one 16 mm., and the fifth, 19 mm., averaging about 15 mm. The following spring, on April 5, 1906, another examination was made, and it was found that 4 of the larvæ had perished. The remaining one was inactive, but began to feed voraciously five days later, and by about April 13 had formed its cocoon and pupated. The moth, a male, emerged on May 14, 1906.

The lengths of the respective stages for this individual were as follows: Egg, 7½ days; combined larval instars, 220 days; pupal instar, 31 days; making a total of 258 days, or 8.6 months for the cycle (from August 28, 1905, to May 14, 1906). This agrees remarkably well with time approximated for the winter generation in the South, where the periods of larval inactivity during the cold months are naturally shorter, and hence growth is more rapid. The individual reared was a descendant of parents from Fort Valley, Ga., mailed to Washington.

NATURAL ENEMIES.

The lesser peach borer has a number of natural enemies, nearly all of which are parasites belonging to the order Hymenoptera.

Elachertus n. sp., of the family Eulophidæ, as determined by Mr. E. S. G. Titus, is probably the most common, and is an internal parasite which is fatal to the host just before pupation. After the host larva has constructed its cocoon the parasitic grubs eat their way through its body and pupate nakedly in the host cocoon, entirely filling it. As many as 138 of these parasites have been reared from

a single larva of the lesser peach borer. It has been found at Odenton and Jessup, Md. (March to May, 1905), and at Fort Valley (April, May, July, 1905), and Myrtle, Ga. (March, 1906).

Bracon mellitor Say is also a rather common parasite of the lesser peach borer, and its method of attack is similar, being fatal to full-grown larvæ in their cocoons. After leaving the body of the host the parasite larvæ spin small compact cocoons side by side, which completely fill the host cocoon. They pass the winter in this condition and emerge the following spring. Thirty-four males and 31 females of this parasite were reared from two host larvæ during April, 1905. The parasite also attacks the larva of the peach borer and has a number of other hosts. It has been found to occur in the same localities as the eulophid parasite, but in Georgia, in 1906, it was rarely met with. It was rather common in Maryland in the spring of 1905. A species of Microbracon was also reared from the larva in Maryland and Georgia.

During 1905, at Fort Valley, Ga., Mr. J. H. Beattie, then of this Bureau, reared *Conura* n. sp. (determined by Titus), from the lesser peach borer. The parasite emerged May 30 from the pupa. Also in May he reared *Pimpla annulipes* Brullé, from the same stage of the host. This is probably the parasite referred to by Bailey (1879). Mr. Beattie also reared a species of Campoplex in May, 1905, and a species of Mesostenus in May and June, at Fort Valley, from this borer, making a total of six hymenopterous parasites, all of which were determined by Mr. Titus.

An undescribed variety of *Dorymyrmex pyramicus* Roger, as determined by Mr. Theodore Pergande, has been observed to attack the larva when exposed during "worming." This ant is very numerous in the peach orchards of Georgia, in the vicinity of Fort Valley, and will prey upon any insect which it is able to overcome. Ordinarily it is unable to get to this borer. Occasionally, however, it will kill recently emerged moths, and any larvæ which may have been overlooked during "worming," but which had been exposed. Mr. Titus reports this ant as being abundant on peach trees at Monticello, Ga., in August, 1905.

It is indicated that birds sometimes extract pupæ from cocoons under loose bark, and Bailey (1879) mentions a woodpecker as extracting larvæ from the trunk of a plum tree.

The value of the parasites of the lesser peach borer is greater than that of its predaceous enemies.

PREVENTIVES AND REMEDIES.

From the fact that this insect prefers to attack trees which have been injured or diseased, or are old, having wounded or checked bark,

it is obvious that anything which will tend to mitigate or prevent these conditions will in turn largely prevent the borer's presence. Therefore proper orchard management, keeping the individual trees in a good, clean, and vigorous condition of health, avoidance of mechanical injury when cultivating, and prompt treatment of wounds made about the body of the tree, are the surest ways to keep the orchard free from this insect.

For its control in orchards already infested there is but one available remedy, namely, cutting the worms or larvæ out of their burrows. This is best done in conjunction with the regular "worming" for the peach borer, the operator taking care to examine all portions of the trees from the roots up to the large limbs above the fork. In doing this it will be necessary to cut away portions of the bark, and wounds so made should be promptly cleaned and treated with some protective antiseptic, as thick Bordeaux mixture or the lime-sulphur wash. All rough, cracked, or diseased areas should be cleaned out and similarly treated, whether they are infested or not, as they form points of entrance for the borers and are in other ways a menace to the life of the tree. The "worming" for this insect should be arranged for the early spring, if convenient, as wounds made at that time heal more readily, and, besides, the larvæ are then pupating in numbers and can be more easily gotten at.

So far as known, other remedial treatments in the shape of caustic or preventive washes are practically worthless in the control of the insect, and their application would be merely a waste of money.

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1884. FERNALD, CHARLES H. Stand. Natl. History (Kingsley), Boston, Vol. II, p. 464.

Mention; attacks plum trees and is similar in habits to the peach borer.

1889. WEED, CLARENCE M. Plum Tree Borer (*Ægeria pictipes*). <American Naturalist, Phila., Vol. XXIII, p. 1108, Pl. XLIII, fig. 7.

Review of Kellicott (1891). Figure.

1890. BEUTENMÜLLER, WILLIAM. *Ægeria pictipes* G. & R. <Annals N. Y. Acad. Sciences, N. Y., Vol. V (1889–1891), p. 204.

Larva on plum; rare.

SMITH, JOHN BERNHARD. *Sesia pictipes* Grt. & Rob. <Cat. of insects found in New Jersey. (Final Rep. State Geologist, Vol. II), Trenton, p. 289.

Mentions the species as generally distributed, but not common.

1891. KELLICOTT, D. S. The Plum Tree Borer (*Ægeria pictipes*). <Journal Columbus (Ohio) Hort. Soc., Vol. V (1890), pp. 16, 19, Pl. I, fig. 7.

Brief notes. Sexes similar and like male peach borer. Plum favorite food; plentiful on wild black and red cherry; probably on cultivated cherry. Larva mainly infests trunk and branches; abundant at Columbus. Recommends knife.

SMITH, JOHN BERNHARD. List Lep. Boreal America, Phila., p. 20.

Listed as *Sesia pictipes* G. & R.

1892. BEUTENMÜLLER, WILLIAM. *Ægeria inusitata* Hy. Edw. <Bul. American Mus. Nat. Hist., N. Y., Vol. IV, p. 172 (author's edit., N. Y., Oct. 18, 1892).

Listed as type in Henry Edwards's collection. One male, Andover, Mass.

1892. KELLICOTT, D. S. Notes on the *Ægeriidæ* of Central Ohio. <Canadian Ent., London, Ontario. Vol. XXIV, p. 46.

Few lines. Quite abundant at Columbus, Ohio. Seriously injuring wild and cultivated cherry, as well as plum.

1893. BEUTENMÜLLER, WILLIAM. *Ægeria pictipes* Grote & Robinson. <Bul. American Mus. Nat. Hist., N. Y., Vol. V, p. 25.

Establishes *inusitata* Hy. Edwards (1881) as a synonym of *pictipes*.

WEBSTER, FRANCIS MARION. Insects reared from Black Knot, *Plowrightia morbosa*. < Ent. News., Phila., Vol. IV, p. 267.

Reared from the fungus on cherry and plum.

1896. BEUTENMÜLLER, WILLIAM. *Sesia pictipes* (Hy. Edwards). <Bul. American Mus. Nat. Hist., N. Y., Vol. VIII, pp. 134–135.

Wrong author given. Synonymy; secondary sexual characters. Larva on plum, wild cherry, juneberry, beach plum. Canada, New Hampshire, Massachusetts, New York, New Jersey, Pennsylvania, Ohio, Illinois, and California.

WEBSTER, FRANCIS MARION. Bul. No. 68, Ohio Agric. Exp. Sta., Columbus, p. 25.

Mention as "the peach borer, *Sesia pictipes*."

1897. BEUTENMÜLLER, WILLIAM. *Sesia pictipes* (G. & R.). <Bul. Amer. Mus. Nat. Hist., N. Y., Vol. IX, p. 220.

Larva under bark of plum, cherry, beach plum, chestnut, and juneberry, usually some distance up from base of tree; also on black knot fungus.

1898. LUGGER, OTTO. The Plum Tree Borer (*Sesia pictipes* G. & R.). <Bul. No. 61, Minnesota Agric. Exp. Sta., St. Paul, p. 119, fig. 63.

Same as Lugger, 1899.

1899. Idem. The Plum Tree Borer (*Sesia pictipes* G. & R.). <4th Ann. Rep. Ent. State Exp. Sta. Univ. Minnesota f. 1898, St. Paul, p. 65, fig. 63.

Short summary account. Apparently increasing. Larva feeds mainly in trunks and branches of wild and cultivated plums and cherries. Figure of adult. Recommends use of pruning knife.

1900. BEUTENMÜLLER, WILLIAM. Synopsis of food-habits of the larvæ of the Sesiidie. <Canadian Ent., London, Ontario. Vol. XXXII, pp. 301, 302.

Sesia larvæ sometimes found in borings made by other insects. Under bark of cherry, plum, and juneberry, some distance from base of tree, or in the limbs.

SMITH, JOHN BERNHARD. *Sesia pictipes* (G. & R.). <Insects of New Jersey. Supplement 27th Ann. Rep. State Bd. Agric., 1899, Trenton, p. 472.

Listed from Newark, Staten Island, Philadelphia, etc. Adults in June and July. Larva on plum, cherry, beach plum, and sometimes peach, but rarely injurious.

1901. BEUTENMÜLLER, WILLIAM. *Sesia pictipes* (G. & R.). <Monograph Sesiidæ of America, North of Mexico. Memoirs American Mus. Nat. Hist., N. Y. Vol. I, pp. 226, 229, 231, 291–292, Pl. XXXI, fig. 10.

Systematic treatment, with synonymy, distribution, description, and food plants; colored figure of female. Moths out June and July. Time of adult emergence (p. 226), synoptic table of larvæ of the Sesiidæ (p. 229), and secondary sexual characters of pupæ (p. 231).

1902. DYAR, HARRISON GRAY. *Sesia pictipes* Grote & Robinson. <List of North American Lepidoptera. Bul. 52, U. S. Nat. Mus., Washington, p. 369.

Distribution given as "U. S."

1903. HOLLAND, W. J. *Synanthedon pictipes* Grote & Robinson. <The Moth Book, N. Y., p. 386, Pl. XLVI, fig. 24.

Brief account. Synonymy and food plants. Adults on wing in June and July. Good colored figure of female.

WASHBURN, F. L. Plum Tree Borer. <Bul. No. 84, Minnesota Agric. Exp. Sta., St. Anthony Park, p. 82, fig. 70. Ibid., Eighth Ann. Rep. State Ent. Minnesota f. 1903.

Sesia. Listed as injurious to plums, with figure of male. Cut out and burn infested parts. Lugger's (1899) figure.

1905. KELLOGG, VERNON LYMAN. American Insects, N. Y., fig. 558 (p. 392).

Figures male. Sesia.

1906. BEUTENMÜLLER, WILLIAM. *Sesia pictipes* Gr. & Rob. <Insects affecting park and woodland trees (Felt), Memoir No. 8, Vol. II, N. Y. State Museum, Albany, pp. 428, 453–454.

Brief account based mainly on Bailey (1879). Description of adults.

QUAINTANCE, ALTUS LACY. The Lesser Peach Borer (*Ægeria pictipes* G. & R.). Yearbk. U. S. Dept. Agric. f. 1905, Washington, p. 335, Pl. XXXI, figs. 3 and 4.

Brief account. Found abundant on old or diseased peach trees in Georgia and Maryland during 1905. Figures both sexes and pupal cast in cocoon. Recommends digging out.

STARNES, HUGH M. Bul. No. 73, Georgia Exp. Sta., p. 154.

Mentioned as the "wild cherry borer (*Synanthedon pictipes*)," and as being often mistaken for male peach borer.

U. S. D. A., B. E. Bul. 68, Part V. D. F. I. I., January 8, 1908.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE LESSER APPLE WORM.

(*Enarmonia prunivora* Walsh.)

By A. L. Quaintance,
In charge of Deciduous Fruit Insect Investigations.

INTRODUCTION.

During the past three years the species known as *Enarmonia prunivora* has been found very commonly infesting the fruit of the apple in various parts of the United States, in some sections so abundantly as to cause serious loss to orchardists, the insect ranking in importance as an apple pest close to the codling moth.

The small, fusiform, flesh-colored larvæ, about three-eighths of an inch long, injure the fruit around the calyx by eating out shallow cavities or boring holes into the flesh from one-fourth to one-half inch or more in depth, in the ripening fruit occasionally penetrating to the seeds. The surface of the fruit, especially in the calyx basin, is also injured, the larvæ working beneath the skin and eating out galleries or large blotch mines, frequently with holes or borings extending more deeply into the flesh. The work of this species resembles rather closely that of the codling moth, and the similarity of the larva to the codling moth larva and a further similarity in the life histories and habits of the two species have doubtless been responsible for the almost complete oversight in the United States of this species as an important enemy of the apple.

HISTORY.

The lesser apple worm was discovered by Walsh in Illinois during July, 1867, in the course of a study of the plum curculio (*Conotrachelus nenuphar* Hbst.). Walsh found the larva in plum and about a month later bred out numerous moths from the same fruit. In the Prairie Farmer for December, 1867, page 359, under the caption "The plum moth," he makes brief reference to his discovery, and the same year, in the First Report of the State Entomologist of Illinois,

page 78, presents figures and a full description, with interesting observations on its feeding habits, etc. He records having bred the moth the year previous from the "black-knot" of plum, from the cockscomb-like hollow gall (*ulmicola* Fitch) on the leaf of an elm, which is produced and inhabited by aphides, and also from a sessile hollow gall about the size and shape of a large pea or small cherry on the leaf of red oak (*Quercus rubra*) and described by Mr. Bassett as *Quercus singularis*.

The rearing of moths from larvæ in curculio-infested plums and "black-knot" and from elm and oak galls led Mr. Walsh to surmise that the larvæ did not infest sound plums and "black-knots," but followed the injury caused by the curculio, and in the elm and oak galls he believed the larvæ to be guests, it being uncertain whether they fed upon the tissues of the gall, upon the gall insects, or, in the case of the elm leaf gall, upon the sugary dust secreted by the aphides. Glover, in his report as Entomologist of the United States Department of Agriculture for 1867, page 73, briefly refers to Mr. Walsh's discovery, adding nothing, however, in the way of personal observations.

In Riley's First Missouri Report, page 65 (1869), brief reference is made to the plum moth in connection with a consideration of the plum-feeding habits of the codling moth, and again in the Third Report, page 6 (1871), it is mentioned as feeding on apples as they mature. Later in the same report (p. 25), under the caption "Two true parasites of the plum curculio," Doctor Riley points out Walsh's error in supposing that *Sigalphus curculionis* Fitch was not a parasite of the plum curculio, but of his plum moth, adding that this last insect had been bred by him from galls (*Quercus frondosa* Bassett), from haws, from crab apples, and abundantly from cultivated apples. In a footnote to an article on the codling moth in his Fifth Report, page 5 (1873), Riley comments further on this species as follows: "There is another and smaller worm, namely, the larva of what Mr. Walsh called the plum moth (*Semasia prunivora* Walsh), which is quite common on haws and apples. It does not penetrate deeply into the apple, but remains around the calyx and generally spins up there, and it so closely resembles the young apple worm that the two might be easily confounded." In the American Entomologist for 1880, page 131, in an article on parasites of the plum curculio, Doctor Riley quotes from his previous article on this subject in his Third Report, page 25.

The species is next mentioned in economic literature by James Fletcher in his report as Entomologist and Botanist to the Central Experimental Farm (Canada) for 1896, page 261, where he records that in Victoria, B. C., in 1895, specimens of a small caterpillar were found feeding on the surface of the fruit of the apple, particularly at the calyx end, eating the skin and mining a short distance beneath

it. Similar larvæ were also received from Lachine Locks, Quebec, some of which, however, were working beneath the skin of the apple and producing large blotch mines. This is also probably the insect complained of by Mr. R. M. Palmer, in British Columbia, in a letter quoted by Fletcher in this same report. In his report for 1898, page 199, Fletcher again comments on this species to the effect that for many years the apple growers of British Columbia had noticed a small caterpillar answering in everything but size to the codling moth larva. The insect had been abundant, but the moth was not obtained until 1897, when a few were bred out by Mr. E. A. Carew-Gibson and forwarded by Doctor Fletcher to this Bureau, being determined here as identical with Walsh's plum moth. Fletcher records having bred this species at different times from apples and haws at Ottawa, from near Toronto, and from Lachine, Quebec. Single specimens had been received occasionally from Quebec and Ontario, but the insect had not been sufficiently abundant to attract attention. Fletcher's observations in British Columbia in the summer of 1897, and also observations by Messrs. Palmer and Carew-Gibson, led these gentlemen to fear that, from the numbers of the insect that were being found, the species might develop into a pest of importance. The great similarity of the injury of this insect to that done by the codling moth was noted, and also its general confusion by growers with this latter species. Later, in a letter to Doctor Fletcher, Mr. Carew-Gibson reported that the insect had been found through all the lower mainland and islands of British Columbia, usually attacking apples, but occurring also quite often in plums and prunes. In concluding his article Fletcher remarks that he considers it unlikely that this insect will ever develop into a serious pest of apples and plums, and regards its injury in British Columbia during the years mentioned as exceptional and due to the failure of wild crabs to produce fruit.

In Bulletin No. 61 of the Minnesota Agricultural Experiment Station, page 295 (1898), Lugger, under the caption "The apple bud moth," presents a brief note, stating that in addition to the apple this insect infests also the plum and cherry, and can become decidedly destructive by eating the buds of apple before they expand, causing in this way more injury than if the leaves were eaten. The larvæ are said to have the habit of feeding inside of cherries, thus causing them to drop.

In his report for 1900 Fletcher states, on the authority of R. M. Palmer, that this insect occurred in nearly all the fruit-growing districts of British Columbia except the Okanogan Valley, but in smaller numbers than in 1898–99.

Without question the larva of this insect is the one referred to by Mr. C. B. Simpson in Bulletin No. 41 of this Bureau, page 23 (1903), on the codling moth, under the heading "Unknown caterpillar work-

ing on outer surface of apples," and the work of which he well illustrated in figure 2 of Plate II. The injured apples were brought to the attention of the Bureau of Entomology by Mr. D. W. Coquillett, in October, 1901, the fruit having been purchased in the open market in Washington; it probably came from near-by orchards in Virginia or Maryland. In November, apples showing this same injury were found by Doctor Howard. A brief description of the larva is given by Simpson; none, however, was reared to the adult stage.

In Bulletin No. 22, new series, of the Division of Entomology, Chittenden, writing of "Insects and the weather; observations during the season of 1899," refers to the plum moth (*Grapholitha prunivora*) as having been quite abundant in some orchards, attacking and destroying both plums and apples.

Webster and Newell, in an article on "Insects of the year in Ohio in 1901" (Bulletin No. 31, new series, Division of Entomology, p. 89), record having bred *Grapholitha prunivora* from berries of a species of Cratægus. This species is again mentioned by Fletcher in his report for 1905, page 25 (1907).

Finally, Messrs. Sanderson, Headlee, and Brooks, in writing of the second brood of the codling moth (Bulletin 131, N. H. College Agric. Exp. Station, p. 25), mention the occurrence in late August of young larvæ, evidently just hatched, eating on the surface of the fruit. These small larvæ of the second brood feed "upon or just under the surface, often around or in the calyx, or where a leaf or another apple comes in contact with the skin, and rarely bore into the apple as does the first brood. Rarely do these worms of the second brood become full grown in this latitude, but late in September, when half grown, they form their winter cocoons. The difference in the food habits of this second brood has been observed by many growers and has led some to the belief that the work is that of a different insect." From the foregoing description of the work and habits of this larva, and from the figure presented of injured apples, it is possible that the insect in question is the species under consideration.

ORIGIN AND DISTRIBUTION.

The lesser apple worm[a] is doubtless a native insect, as indicated by its feeding on indigenous species of Cratægus, crab apples, and wild plums. The fact that it attacks cultivated plums and apples is not surprising in view of the close relationship of these wild and domestic fruits, and finds parallel in the case of numerous other American species which have become destructive to cultivated crops.

[a] This name, first used by Fletcher for this species, is adopted in preference to Walsh's name, "plum moth," on account of the greater injury to apples.

In the literature of the species it has been recorded from the following States and Provinces: Illinois (Walsh); Missouri (Riley); British Columbia, Ontario, and Quebec (Fletcher); Minnesota (Lugger); Ohio (Webster and Newell); District of Columbia (Simpson and Chittenden), and New Hampshire (?) (Sanderson, Headlee, and Brooks). The insect has been bred by the Bureau of Entomology from fruit from the following places: Tazewell, Tenn.; Raleigh, N. C.; Macy, Ind.; Niagara-on-Lake, Canada; Youngstown, N. Y.; North East, Pa.; Baltimore, Riverdale, and Arundel, Md.; Pomona and Fort Valley, Ga.; Arlington, Afton, and Winchester, Va.; Nebraska City, Nebr.; Bentonville and Siloam Springs, Ark.; Garrison, Tex.; Ardmore, Ind. T.; Albert Lea, Minn.; Agricultural College, Mich; Tryon, N. C., and Gerrardstown, W. Va.

FOOD PLANTS AND DESTRUCTIVENESS.

Walsh bred this species from plum and "black-knot" and from elm and oak galls; Riley bred it from haws, crab apples, cultivated apples, and also from galls (*Quercus frondosa* Bassett). Fletcher records it from apples, haws, plums, and prunes, and Lugger states that it infests the apple, plum, and cherry, feeding on the buds of the apple before they expand and working within the fruit of the cherry. It has been noted by Chittenden as feeding on plum and apple, and on this latter fruit by Simpson and by Messrs. Sanderson, Headlee, and Brooks. Bureau of Entomology records show that this species has been bred from apple, *Crataegus* spp., peach, and plums—wild and cultivated. The larva of what proved to be this insect was also found during the summer of 1907 in the Ozark regions of Arkansas, boring down the terminal shoots of young, vigorous, growing apple trees, and also infesting "water sprouts" on older trees.

While the insect has frequently been bred from cultivated varieties of plums of the Japanese, Chickasaw, Americana, and Domestica types, including prunes, its injuries to these fruits have not thus far been observed to be very extensive. The larvæ feed upon the young plums early in the season, causing them to drop, and later bore into the maturing fruit. Their attack on apples, however, in some localities results in very important loss.

Injury to young apples by the first brood of larvæ may be quite extensive. Thus, in an investigation of the subject by the writer in apple orchards in the Ozark regions of Arkansas, from July 18 to 25, the past summer, this species was found to be quite as abundant as the codling moth; and this conclusion was reached also by Mr. E. L. Jenne, of this Bureau, who was stationed at Siloam Springs, Ark., for the season. At picking time the fruit from unsprayed trees in this region was quite as frequently injured by this species as by the codling moth, the two insects in unsprayed orchards injuring a

large percentage of the crop. Almost equally serious injury from the lesser apple worm to fruit at time of harvesting was noted by the writer in orchards in the vicinity of Afton, Va., during the fall of 1905. Observations on this species by Mr. Fred Johnson, of this Bureau, at North East, Pa., during 1906, indicate that it is in that locality quite as abundant and destructive to apples as is the codling moth, attacking also Domestica varieties of plums. During the summer of 1906, in orchards in southeastern Nebraska, this insect was observed by Mr. Dudley Moulton, of this Bureau, and the writer to be everywhere abundant and destructive, and late in the season almost equally so with the codling moth.

Frequent examinations in the Washington markets of apples in barrels, coming mostly from orchards in Maryland, Virginia, and West Virginia, show often an injury by this species of from 15 to 20 per cent of the fruit, some of this occurring after the apples have been barreled, as proved by the presence of the larva. From these statements may be judged something of its present status and capabilities as an apple pest.

CHARACTER OF INJURY.

The great similarity of the injury to apples by this species with that of the larva of the codling moth and the similarity of the larva itself to an immature apple worm no doubt account for the fact that its considerable economic importance in the United States has been thus far overlooked. There are, however, certain differences in the character of injury of the two species, and in most cases the work of the lesser apple worm, in the absence of the insect itself, may be positively recognized. Injury by the first brood is perhaps confined more to the calyx end of the apple than later in the season. Cavities or holes from one-fourth to one-half inch deep are eaten into the flesh more or less around the calyx lobes and core within, the larvæ eating directly through the skin at the base of the sepals, or more commonly entering the calyx cavity, whence they bore out into the flesh and under the skin, this latter form of injury being quite easily overlooked. Very commonly, also, more or less winding, but eventually blotch mines are made under the skin in the calyx basin, often extending out to the sides; such mines also occur on the sides of the apples, especially where two are in contact or where an apple is touched by a leaf. Much of the fruit thus injured falls or ripens prematurely.

Later in the season the blossom-end injury is about as described, though there is a tendency on the part of the larva to penetrate deeper into the fruit, working in numerous cases observed quite to the seeds. The surface injury, however, is now rather more common, the larva eating out just under the skin large irregular, more or less winding or blotch mines, which are quite conspicuous. Under the

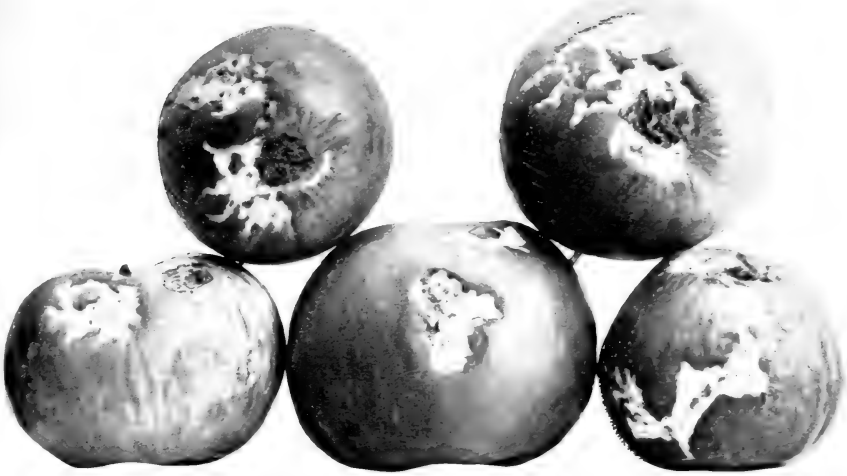


FIG. 1.—APPLES SHOWING SURFACE INJURY BY LESSER APPLE WORM (ENARMONIA PRUNIVORA). (FROM SIMPSON.)

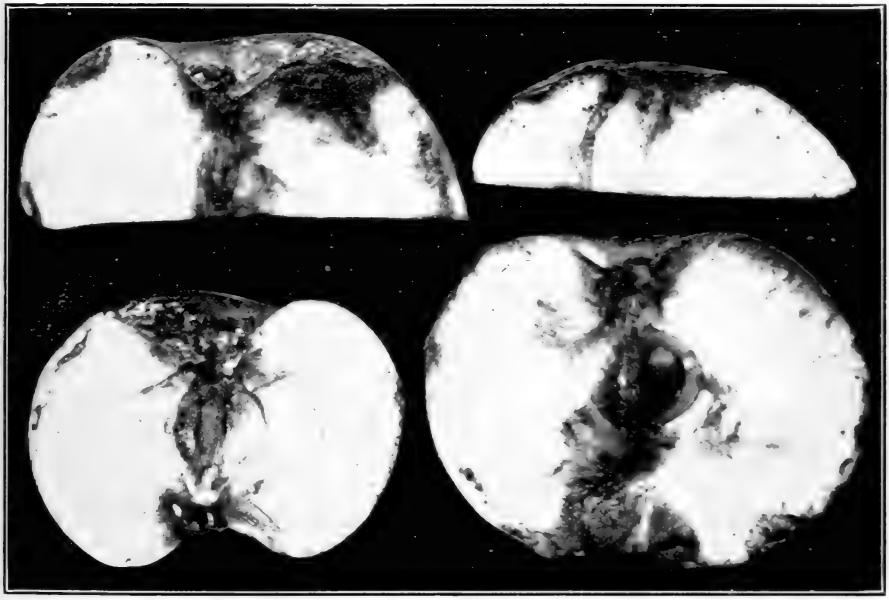


FIG. 2.—PORTIONS OF APPLES SHOWING WORK OF LESSER APPLE WORM (ENARMONIA PRUNIVORA).

In lower figures, injury at calyx and stem ends; in upper figures, injury to flesh under blotch mines. (Original.)

skin the larva as it grows may excavate cavities or holes extending into the flesh from one-fourth to one-half inch, or deeper. This surface injury, which may occur on the ends or sides, while perhaps not more serious in its effect than the borings at the calyx and stem ends, is more conspicuous and greatly disfigures the fruit. (See figs. 1 and 2, Pl. VII.)

Larvæ of this species apparently do not reach full development as early in the fall as those of the codling moth, and many find their way into the barrels, where they continue to feed, in some instances observed doing considerable damage, the introduction of the infested fruit being favored by the inconspicuous nature of the injury when occurring in the ends of the apples.

DESCRIPTION.

Egg.—The egg stage has not been observed.

Larva.—Full-grown larvæ (at time of leaving fruit in fall for hibernation) measure from 6 to 8 mm. in length. The body is some-

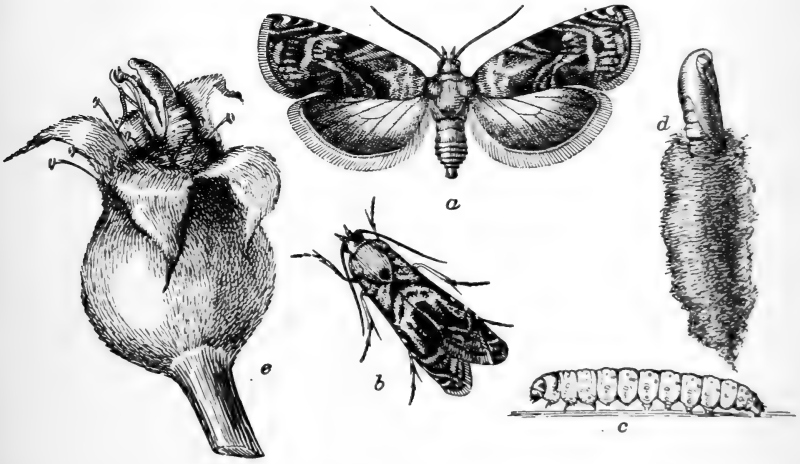


FIG. 11.—Lesser apple worm (*Enarmonia prunivora*): *a*, Adult or moth; *b*, same, with wings folded; *c*, larva; *d*, pupa in cocoon, ready for transformation to adult; *e*, young apple, showing at calyx end empty pupa skin from which moth has emerged. Enlarged about three times. (Original.)

what fusiform, uniformly reddish flesh-colored above, lighter below, the intensity of coloring varying in different individuals from deep reddish pink or purplish to almost or entirely white. Head bilobed, retractile, brown to dark brown, in some specimens more or less mottled with dusky. The ocellar spots, a spot caudad on cheek, and tips of the well developed and strongly toothed mandibles, black; sutural lines dark brown to blackish; width 0.75 to 0.85 mm., and about as long as wide. Thoracic shield prominent, yellowish, transparent,

often with darker markings on caudal margin near median line. Anal plate brownish, with comblike structure on caudal curvature composed of from 5 to 7 closely set dark brown spines, the outer spine on each side considerably reduced. Spiracles small, dark brown; thoracic legs well developed, whitish, distal end dark, claw black. Abdominal prolegs well developed, each with a single circle of from 25 to 27 strongly curved, sickle-like hooks. Tubercular areas disk-like, whitish, with a single, slender, light-colored seta. On third abdominal segment: Tubercle I central, on dorso-lateral region; tubercle II caudo-ventrad of I, on posterior annulet; tubercle III about its width above spiracle; tubercles IV and V coalesced, directly below spiracle, about twice as far from it as is tubercle III, the seta of tubercle IV being considerably reduced; tubercle VI caudo-ventrad of IV and V, and tubercle VII with three setæ situated near base of proleg.[a] (See fig. 11, *c*.)

Cocoon.—About 6 mm. long and a third as wide. Exterior more or less covered with bits of bark or other material, concolorous with surroundings; within densely lined with whitish silk. (See fig. 11, *d*, *e*.)

Pupa.—About 5 mm. long. Color uniformly brown, except thoracic region, leg and wing sheaths, which, as pupa nears maturity, are darker. On dorsum of abdominal segments 3 to 7, between the spiracles on each side, are 2 rows of short, stout spines, projecting caudad, one row near cephalic border of segment and one near center or on caudal margin, the spines of caudal row smaller and more numerous. Remaining segments (except 1 and 2, which are spineless) with but a single row. Anal segment truncate, the 7 to 8 stout spines set on caudal margin. Cremaster of from 5 to 8 slender hairs hooked at tip and arising about equally distant from each other on caudal region of anal segment. Spiracles slightly elevated, dark brown. Wing sheaths and those of third pair of legs about equal in length and reaching middle of fourth abdominal segment. In emergence of adult, the pupa works out from cocoon about one-half its length, the empty exuvium remaining in this position in the cocoon. (See fig. 11, *d*, *e*.)

Adult or moth.—The description of the adult as given by Walsh in his first report as Illinois State entomologist, page 80, is herewith presented:

Ground-color of front wing, black. The basal one-fourth irregularly covered with rust-red, so as to leave only a few black markings. On the costa, and rather more than one-third of the way to the apex of the wing, a pair of streaks obliquely directed toward the posterior angle of the wing; the inner streak of

[a] The description of the larva by Simpson (Bulletin No. 41, Division of Entomology, p. 23) is not entirely in accord with the above. The length is said to be five-eighths inch, and for the "pre-spiracular" tubercle three setæ are recorded.

the pair is on its extreme costal end clear white, elsewhere pale steel blue, and extends nearly to the disk of the wing, where it almost unites with a subquadrangular pale steel-blue blotch, which is usually seen there without difficulty, though it is occasionally subobsolete; the outer streak of the pair is only half as long as the inner one, towards which it converges very slightly without actually uniting with it, and is colored in the same manner. Further along on the costa, and not quite two-thirds of the way to the apex of the wing, there is another such pair of streaks, parallel with the first pair and similarly colored, the inner one of which, when it has become as long as the inner one of the other pair, sweeps in a gradual curve round the disk of the wing till it almost attains the inner margin, a little way from its tip; while the other streak of the two is so very short that the steel-blue part of it is subobsolete and can only be seen in certain lights. Beyond this second pair of streaks, and rather more than three-fourths of the way along the costa to the apex of the wing, is another streak, parallel with all the others and similarly colored, which strikes the outer margin about one-third of the way from the apical to the posterior angle, where it terminates in a pale streak in the fringe. And beyond this again, and equidistant from it, from each other, and from the apex of the wing, there is on the costa a pair of short white streaks, the inner one much the shorter of the two. Thus along the costa we have a series of 7 very conspicuous short white streaks, arranged 2, 2, and 3. The terminal one-fourth of the front wing is mostly rust-red, with a series of abbreviated, black, longitudinal lines, springing from the other edge of the curved prolongation of the inner one of the second pair of streaks on the costa; and beyond these short black lines are two very oblique, short, pale steel-blue streaks, one springing from the posterior angle and the other a little above it from the outer margin. Disk of the front wing rust-red, with many indistinct, short, black, longitudinal lines, and on its center the pale steel-blue blotch already referred to. On the middle of the inner margin, a large elongate-triangular, rust-red patch, the apex of the triangle directed towards the apex of the wing and attaining the disk, the base of the triangle occupying nearly one-fourth of the inner margin. The triangular patch is bisected lengthwise by a very elongate and slender black triangle, the apex of which attains its apex; and the rust-red space on each side of this last triangle is again indistinctly bisected lengthwise by a still more elongate triangle composed of confluent black atoms. Fringe dusky, with a black basal line all along it. Hind wing dusky-gray at base, shading into black at tip. On the middle of the outer margin in the male, but not in the female, an elongate semioval patch (fig. 3*a*) of metallic brassy scales, brighter in certain lights. Fringe of the male (fig. 3*a*) long, sparse, and grayish-white on its anal half, short, dense, and dusky with a basal black line for its remaining half. Fringe of the female (fig. 3) nearly of uniform length, coarse and dusky throughout on the half next the wing, then suddenly fine and grayish-white on its outer half. Body brown-black. Face and palpi grayish-white. Shoulder-covers largely tipped with dull rust-red. Tips of the abdominal joints pale fuscous above. Legs dusky. All beneath, including the legs, with a more or less obvious silvery-white reflection. [See fig. 11, *a*, *b*.]

SEASONAL HISTORY AND HABITS.

Our knowledge of the life and habits of the lesser apple worm is still very incomplete, and it is hoped that numerous points may be cleared up during the course of another season. It is certain, however, that in several important respects the life habits are quite similar to those of the codling moth.

So far as observed, the winter is passed in the full grown larval condition. Cocoons are formed in cracks and crevices of the bark of apple trees, under bark scales, and probably wherever suitable protection may be found. Observations by Mr. S. W. Foster, of the Bureau of Entomology, October 21, 1907, in an orchard badly infested with this insect in the vicinity of Washington, revealed larvæ in cocoons in cracks in the bark and crevices, the small size of the larvæ enabling them to work into very small openings. In a breeding cage under out-of-door conditions, in the insectary yard at Washington, larvæ from fruit of Cratægus spun cocoons in cracks in the bark and under the bark scales of a portion of a limb of pear tree which had been introduced, and a few larvæ penetrated as deeply as possible in cracks in one end of the limb. The cocoons are made of bits of surrounding bark and are thus rendered difficult of detection; the interior is lined with whitish silk. First-brood larvæ often pupate in the calyx end of apples, or in plums, after these have fallen to the ground, and several instances have been observed where pupation has occurred in small, dry, and withered apples on the trees, and also in the fruit of Cratægus. In breeding cages larvæ have been observed to fold over flaps of apple leaves, making their cocoons in the protection thus formed. A few larvæ have been found under bands around apple trees, as used for capturing codling-moth larvæ, though not in sufficient numbers to indicate that the larvæ in summer go to the trunks of trees in numbers for pupation.

The overwintering larvæ pupate in the spring, the moths probably emerging about as is true for the codling moth. Observations by Mr. Fred Johnson, at North East, Pa., are to the effect that full-grown larvæ are abundant in apples during early July. At Siloam Springs, Ark., the past summer, Mr. E. L. Jenne secured moths June 20, 25, and 30, from apples collected May 31, and full-grown larvæ were found in apples that were collected at Afton, Va., June 26, 1907, the moths emerging July 12, and subsequently to August 21; also full-grown larvæ were found in apples sent in by Mr. L. M. Smith, Raleigh, N. C., June 8, 1907, and moths emerged June 28, July 1, and subsequently until the 23d. From apples from Pomona, Ga., received June 4, one moth emerged July 8. Apples collected at Winchester, Va., June 15, by Mr. S. W. Foster, gave adults July 3 and 9. Other breeding records for 1907 bear out those cited, though it should be noted that moths have been reared from fruit over practically the entire season, indicating an overlapping of generations perhaps more pronounced than is the case with the codling moth. However, in the Ozarks, in Arkansas, by July 18 to 25, 1907, 75 per cent of the fruit injured by this insect had already been deserted and the remaining larvæ were practically all full grown.

At Nebraska C[illegible], Nebr., during 1906, Mr. Dudley Moulton found full-grown larvæ in apples during late June and early July, moths issuing from July 6 to August 24, reaching their maximum, however, during late July and early August. The pupal stage was found to last from fourteen to sixteen days.

In 1905 full-grown larvæ were found in wild plums as early as April 28, at Fort Valley, Ga., and during the same spring mature larvæ were received in a sending of Japan plums from Garrison, Tex., by Prof. F. W. Mally, under date of May 20; and also in wild plums sent in by Mr. C. R. Jones, from Ardmore, Ind. T., a few days later.

At least two annual generations of larvæ are evident, though in the more northern States the second may prove to be only a partial one. Larvæ are notably later in leaving the fruit in the fall than is true of the codling moth, and are hence very commonly found at picking time, and it is likely that their occurrence has thus led to belief in an additional brood of the latter species, especially on the part of orchardists. Owing to their comparatively small size the larvæ may be readily overlooked, especially when in the calyx end, and infested fruit thus often goes into the barrels. In several instances which we have noted, important injury has been done by the larvæ to barreled fruit, the disfigurement of the surface being especially common.

IDENTITY.

The recorded feeding of this insect upon such diverse food as the "black-knot" of plums, elm and oak galls, and upon apples, plums, and Cratægus, naturally brings up the question of the identity of the insects secured from these several sources. On this point Walsh says:[a]

> Three specimens bred from Black-Knot Aug. 31–Sept. 7, three others bred from the Elm Gall (*Ulmicola* Fitch) July 24–Aug. 5, and a single one bred from Oak-Gall (*Q. singularis* Bassett) on Sept. 2, none of them differed from the plum-fed specimens in any important point. I sent a single specimen bred from the Black-Knot to the late Dr. B. Clemens about a year before his lamented death; but he never, so far as I know, investigated its classification. For the satisfaction of the incredulous I may add that I sent specimens bred respectively from the Plum and Elm Gall to the distinguished English entomologist, H. T. Stainton, who is well known to have made the smaller moths his special study for years; and that he agrees with me that they are perfectly "identical."

Also according to Stainton, as stated by Walsh, the species is most closely allied to the European *Semasia janthinana* Dup., which has also been bred from gall-like growths on hawthorn twigs. Riley also records breeding the species from galls (*Quercus frondosa* Bass.), in the Third Missouri Report, page 25. No further records of the insect

[a] First Report State Entomologist of Illinois, p. 81.

occurring in galls or black-knot have been found by the writer, and we have not been able to breed it from these, in the limited trials thus far made.

The moths which we have secured during the past three years from plum, apple, and Cratægus, and from terminal shoots of young apple trees, have been carefully compared by Mr. August Busck, of this Bureau, whose assistance we desire to acknowledge in this connection, and all have been found to belong to the same species, namely, *Enarmonia prunivora* Walsh.

PARASITES.

Only one hymenopterous parasite is recorded from this species, namely, *Mirax grapholithæ* Ashm., in apples from Washington, D. C., May 3, 1881. The insect which Walsh supposed was parasitic on this species, namely, *Sigalphus curculionis* Fitch, as shown by Riley is a parasite of the plum curculio (*Conotrachelus nenuphar* Hbst.), as has been known for many years.

METHOD OF CONTROL.

From the similarity in feeding habits of the lesser apple worm and the codling moth it would appear likely that proper spraying with arsenicals for the latter insect would also be effective in controlling to a considerable extent the former, and observations in orchards in Nebraska, the Ozarks, and Virginia show that this is the case.

The larvæ of the first generation, which mostly attack the fruit at the calyx end, are no doubt destroyed by the poison held in the calyx cavity, though, as has been noted, larvæ often bore into the fruit at the base of and outside of the calyx lobes. In some instances examined the calyx cavity and stony tissue of the core just under the skin have been left almost or quite intact. Feeding in this way larvæ would scarcely be poisoned. The comparatively small numbers taken from under bands of burlap around the trees, as used for the codling moth, show but little value from this procedure as used specifically against the lesser apple worm. Thorough spraying for the codling moth will perhaps best serve to keep the other pest in control, and where applications are made for the second brood of the former insect, these certainly will be of great use in reducing injury from the lesser apple worm late in the season.

U. S. D. A., B. E. Bul. 68, Part VI. D. F. I. I., April 24, 1908.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

GRAPE ROOT-WORM INVESTIGATIONS IN 1907.

By Fred Johnson,

Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

For several years past the control of certain insect enemies of the grape has been a problem of increasing importance with the vineyardists of the Lake Erie valley. The insect causing most alarm is the grape root-worm (*Fidia viticida* Walsh). It was in 1899 that serious injury to the grape vine, which proved to be the work of this pest, was first noticed in the famous Chautauqua grape region, at Ripley, N. Y. For several years previous to the discovery of this insect in Chautauqua County, it had made serious inroads into the vineyards of the Ohio grape region, and was, in 1895, the subject of investigation by Prof. F. M. Webster, then entomologist of the Ohio Agricultural Experiment Station, to whom we are indebted for the first records of its complete life history and methods of control, a report of which was published in Bulletin No. 62 of the Ohio Agricultural Experiment Station.

Since 1900 this pest has been the subject of investigations in Chautauqua County, by Dr. E. P. Felt, State entomologist of New York, and Prof. M. V. Slingerland, of the Agricultural Experiment Station at Cornell University, both of whom made a life-history study of the insect and conducted field experiments in jarring and spraying the vines to reduce the number of beetles. The results obtained by these gentlemen are embodied in Bulletins 59 and 72, New York State Museum, by Dr. E. P. Felt, and in Bulletins 184, 208, and 224, of the Cornell University Agricultural Experiment Station, by Prof. M. V. Slingerland. In Farmers' Bulletin No. 284, on Insects and Fungous Enemies of the Grape East of the Rocky Mountains, by Messrs. A. L. Quaintance and C. L. Shear, the grape root-worm is described, and its life history and methods of control are briefly stated.

A BRIEF CONSIDERATION OF VINEYARD CONDITIONS.

During the past eight or ten years changes have occurred in both market conditions and in the age, area, and productivity of vineyards throughout the Lake Erie valley, which deserve brief consideration for full appreciation of the present active interest of vineyardists in this insect problem.

In 1900, when the grape root-worm first appeared in injurious numbers in the Lake Erie valley, the grape industry was just emerging from a period of depression which had caused, for several years previous, an almost complete cessation in planting of new vineyards. The period of low prices had resulted in indifferent care, amounting in some cases to positive neglect, thus creating a condition very favorable to the increase of this pest. The tendency of most vineyardists at that time was to pull out declining vineyards rather than to go to the expense of fighting insect foes. Furthermore, the fact that practically all vineyards had been for several years in bearing and had a well-established root system permitted the insect to become thoroughly disseminated through them before the unsuspecting owners were aware of its presence in numbers sufficient to affect the vigor of their vines. Thus it happened that a combination of circumstances conspired to favor a general spread of the insect without creating widespread alarm.

With the steady rise in the value of grapes since 1900, however, this condition has been reversed. Thousands of acres of new vineyards have been planted, and the more progressive vineyardists are commencing to appreciate fully what an enormous amount of injury has been done to their old vineyards, and are greatly alarmed at the rapidity with which many young vineyards are falling a prey to this pest.

A study of the production of grapes in the Lake Erie valley since the advent of the grape root-worm shows a steady decline in yield. The figures given below are taken from the "Chautauqua Grape Belt," a newspaper which is largely devoted to the grape interests of that region, and every year publishes carefully gathered statistics on grape production.

Grape crop production from 1900 to 1907.

	Carloads.
Yield for 1900	8,000
1901	6,669
1902	5,062
1903	2,954
1904	7,479
1905	5,365
1906	5,463
1907	5,186

The true significance of these figures, however, is not realized unless we take into consideration that there are now nearly 10,000 acres more of bearing vineyard than there were in 1900, which should of themselves produce nearly 1,800 carloads of fruit.

An analysis of the 1907 crop report brings out forcibly the deterioration of the old established vineyards. In the three townships of Portland, Westfield, and Ripley, in which there has been much less new planting than in the townships at either the eastern or western extremities of the grape belt, and which therefore come nearer to giving the true decline of old vineyards, there was a decrease of 585 carloads of grapes below the crop for 1906. Placing the value of grapes at $25 per ton, the lowest price paid for grapes in 1907, there was a shrinkage in value approaching $175,000 in these three townships. While some of this decline in production may be due to depletion of soil, lack of proper cultivation, and adverse weather conditions, yet many vineyardists who are careful observers are now convinced that a high percentage of this loss is due directly to the ravages of the grape root-worm.

It is a fact notorious to all vineyardists that wood production in nearly all vineyards has greatly decreased. In the issue of the "Chautauqua Grape Belt" for January 7, 1908, the statement is made, in predicting a light crop for 1908, that in most vineyards the wood growth is 65 per cent of the normal wood growth of several years ago, and in many vineyards is as low as 25 per cent. Extended observations during the past year convince the writer that this statement is by no means exaggerated.

It was because of the existence of such conditions as are described above that the vineyardists of North East, Pa., became alarmed for the future of their vineyards, and appealed to the Secretary of Agriculture for assistance. In compliance with this request investigations were commenced by the Bureau of Entomology in the spring of 1907.

WORK UNDERTAKEN AT NORTH EAST, PA.

The main features of the work against the grape root-worm at North East, Pa., during the past summer have been: (1) A close study of vineyard conditions to determine the amount of injury for which this insect is responsible, and the amount of injury done to vines of various ages; (2) the conducting of large-scale spraying experiments in vineyards but recently infested, with a view to furnishing protection from the insect and maintaining the present standard of crop production; (3) beginning large-scale experiments to determine the possibility of bringing badly injured vineyards up to a state of profitable production, and to ascertain the best means of furnishing protection to young vineyards just coming into bearing.

EXTENT OF INJURY TO NEWLY BEARING VINEYARDS.

As an illustration of the extent of injury done by this pest to young vineyards which came under the writer's observation during the past summer, the condition of a block of vineyard growing on a level piece of ground in a clay loam soil near the lake shore may be cited. The vines had borne but three crops, and previous to the attack of the grape root-worm were very thrifty. The original planting consisted of 3,234 vines. An examination of the vineyard on June 17, 1907, showed that 543 vines had been so badly injured by the grape root-worm that they had to be cut back to the ground; 897 vines were cut back to the lower wire and bore no fruit that season, and the remaining 1,794 vines were cut back to one or two canes. This treatment, made necessary by root-worm injury, resulted in a curtailment of 75 per cent of the crop.

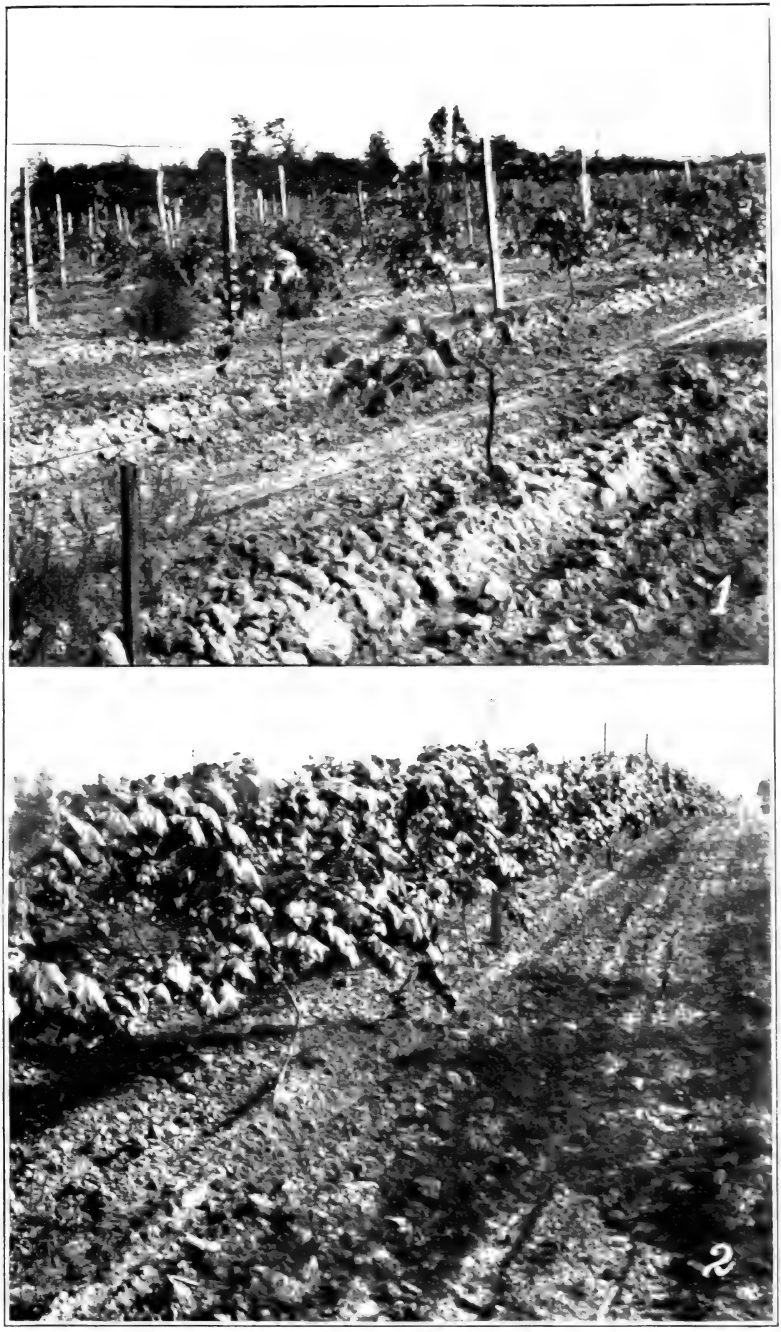
Figure 1, Plate VIII, shows the condition of the above-mentioned vineyard September 2, 1907. Figure 2, Plate VIII, shows vines in a younger vineyard only a few yards distant, bearing their first crop of fruit and not yet infested by the grape root-worm. (The owner informed the writer that at the same age the vines shown in figure 1 were quite as thrifty as those shown in figure 2.)

Another young vineyard, 6 years old, on a loose gravel soil, showed an even worse condition. In one section of 1,620 vines, 485 vines were killed outright in a single season, and nearly all the rest of the vines were so seriously injured that they had to be very severely cut back. The crop record of this vineyard is given below, and shows a decline in crop value, in 1907, of $379.80, or 87.17 per cent less than in 1906.

TABLE 1.—*Crop record of vineyard injured by grape root-worm.*

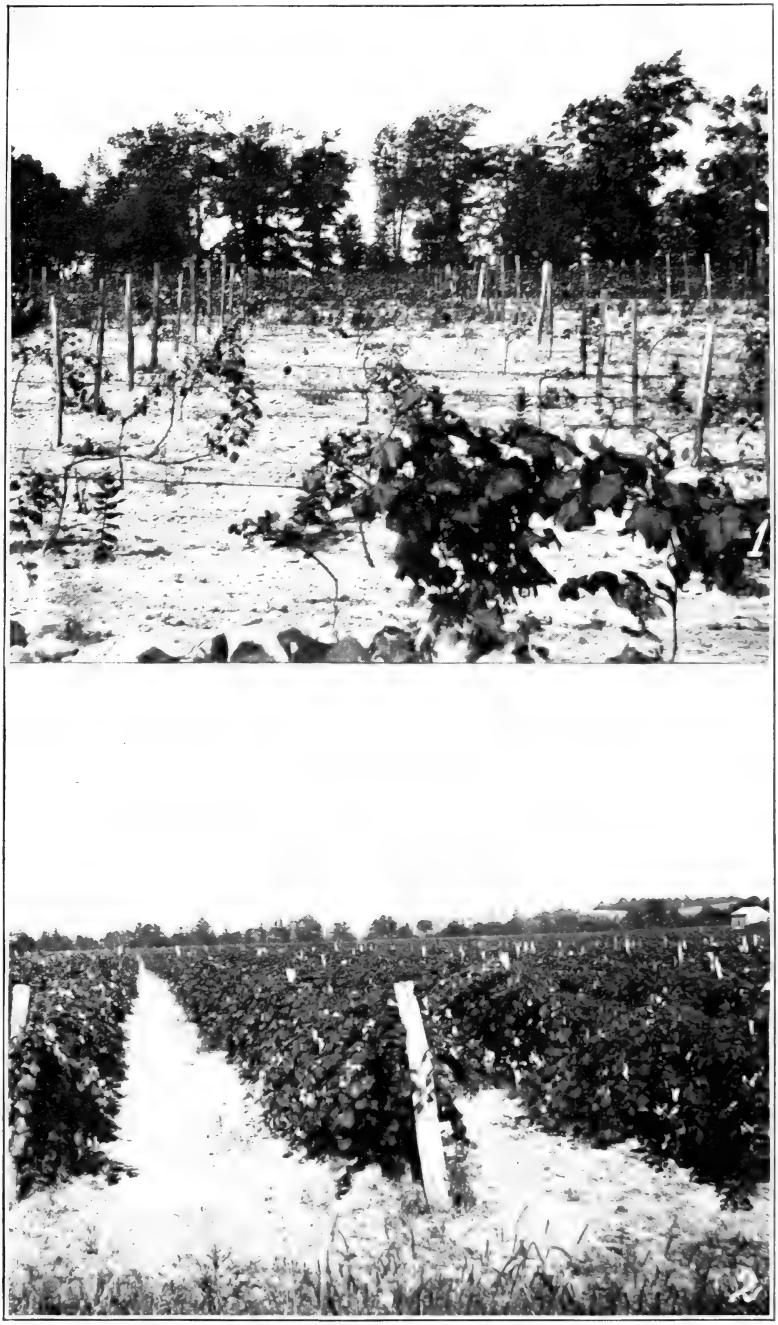
Year.	Number of trays.	Number of baskets.	Net weight.	Value of crop.
			Pounds.	
1904	295	None.	11,630	$127.51
1905	613	696	23,705	410.77
1906	581	588	21,130	435.72
1907	93	None.	3,195	55.92

Figure 1, Plate IX, shows the stunted condition of the vines in the above-mentioned vineyard, as a result of the grape root-worm injury. Figure 2, Plate IX, shows a normally thrifty uninfested vineyard at North East, Pa. It should be stated in addition that both of these injured vineyards had received the best of care, so far as cultivation and general management are concerned, with the exception of spraying the vines to protect them from the beetles, and previous to 1906 both vineyardists were highly pleased with the vigorous condition of their vines. The illustrations cited above are



VINES INJURED BY GRAPE ROOT-WORM COMPARED WITH UNINJURED VINES.

Fig. 1.—Six-year planted vines making but a weak growth because of injury to roots by grape root-worm. Fig. 2.—Two-year planted vines not yet attacked by grape root-worm. At the same age vines in figure 1 were equally thrifty. (Original.



VINES INJURED BY GRAPE ROOT-WORM COMPARED WITH UNINJURED VINES.

Fig. 1.—Young vines almost ruined by feeding of grape root-worm upon their roots. Fig. 2.—A normally thrifty vineyard at North East, Pa., uninfested by grape root-worm. (Original.)

by no means exceptional, and a careful survey would reveal hundreds of acres of these newly bearing vineyards in various stages of decline. It was to these new vineyards that the vineyardist looked for the maintenance of the industry in the future, but their present condition shows that when unprotected from the grape root-worm they succumb to the attacks of this pest even more rapidly than do old established vines.

This rapid decline in young vines, due to grape root-worm attack, has opened up the question of the advisability of attempting to renovate these old, run-down vineyards, some of which are now yielding a ton or less of grapes per acre and of which there are several thousands of acres throughout the grape belt.

RENOVATION EXPERIMENT ON AN OLD, RUN-DOWN VINEYARD.

Early in the spring of 1907 a vineyard of 10 acres was secured at North East, Pa., which had been so badly injured by the grape root-worm that the decline in grape production had fallen from $3\frac{1}{4}$ tons of grapes per acre, in 1905, to three-fourths ton per acre in 1907. The vineyard is to receive severe pruning, thorough cultivation, liberal applications of fertilizers, and thorough spraying. This treatment is to continue for a series of years.

The results of this treatment during the past summer are an increased growth of canes over last year, and a great reduction in the deposition of grape root-worm eggs—a direct outcome of the poison spray application, as indicated in the following table:

TABLE II.—*Showing egg deposition on sprayed and check plats.*

CHECK (UNSPRAYED) PLAT.

Dates of application.	When examined.	Number of egg clusters found.				Estimated number of eggs.	Number of vines.	Number of canes.	Average number of eggs.	
		Large.	Medium.	Small.	Total.				Per vine.	Per cane.
	August 12...	97	150	238	485	11,730	25	76	469.2	154.37

SPRAYED PLATS.

Formula: 5 pounds blue vitriol (copper sulphate), 5 pounds lime, 3 pounds arsenate of lead, 50 gallons water.

PLAT NO. 1.										
July 13..... July 22.....	August 13...	1	21	34	56	1,440	25	56	57.6	25.71
PLAT NO. 2.										
July 13..... July 22.....	August 13...	4	17	25	46	960	25	85	38.4	11.29

As has been previously stated, the wood growth in this vineyard was light as a result of serious injury to the roots of the vines by the

grape root-worm and from severe pruning in the spring. For this reason it might be urged by some that this experiment was not a fair test of the efficacy of a poison spray, because, it is said, beetles desert vineyards in this condition for those having a dense foliage. That there were a large number of beetles present, however, is shown by the heavy deposition of eggs in the untreated check, even though the foliage was light.

SPRAYING EXPERIMENT IN A NEWLY INFESTED VINEYARD.

Since a part of the campaign against this pest is to determine if thorough and timely spraying, conducted for a series of years, will prevent the deterioration of thrifty vineyards but recently infested, an experiment was planned in another vineyard. This vineyard is 20 years old, on gravel soil, making a good growth of canes and luxuriant foliage. It is infested with the grape root-worm, but is not yet showing evidence of deterioration. The block contains about 6 acres; 1 acre was left unsprayed for check and the method of examination to determine results was the same as in the preceding experiment.

The following table gives the record of egg deposition in this block, as a result of the spray applications:

TABLE III.—*Showing egg deposition on sprayed and check plats.*

CHECK (UNSPRAYED) PLAT.

Dates of application.	When examined.	Number of egg clusters found.				Estimated number of eggs.	Number of vines.	Number of canes.	Average number of eggs.	
		Large.	Medium.	Small.	Total.				Per vine.	Per cane.
	August 2.....	52	136	213	401	8,810	25	69	352.4	127.67

SPRAYED PLATS.

Formula: 5 pounds blue vitriol (copper sulphate), 5 pounds lime, 3 pounds arsenate of lead, 50 gallons water.

PLAT NO. 1.										
July 15..., July 23...	August 2.....	4	13	13	30	720	25	72	28.8	10
PLAT NO. 2.										
July 15..., July 23...	August 2.....	4	19	20	43	970	25	61	38.1	15.9

METHODS OF RECORDING RESULTS.

The figures on egg deposition given in the tables above were obtained by carefully removing all of the loose bark from the bearing canes and the trunks of 25 consecutive vines, and recording the number of egg clusters found. Since the egg clusters varied in size, they were classified—after the eggs in a large number of clusters had been counted to ascertain the actual number—as *large*, when containing 50

eggs or over; *medium*, when containing about 30 eggs; and *small*, when containing about 10 eggs. Examinations were made in three parts of the vineyard. An unsprayed check plat of 1 acre was left on one side of the vineyard and the egg clusters found on 25 consecutive vines, at a date after the maximum number of eggs had been deposited, were recorded in the manner just described. A similar examination was made on 25 consecutive vines in the sprayed portion, six rows over from the check plat, and a further examination on 25 sprayed vines on the opposite side of the vineyard, the main object of this last examination being to determine the uniformity of egg deposition throughout the vineyard.

RECOMMENDATIONS BASED ON OBSERVATIONS AND RESULTS OF SEASON'S WORK.

The work of the past season, at North East, Pa., indicates that thorough and timely spraying of infested vines with arsenate of lead will, by preventing the deposition of a sufficiently high percentage of eggs, reduce the number of grape root-worms to such an extent that they will not seriously affect the growth of the vines. In order to make the spray effective, however, the first application must be made either immediately before, or as soon as the first beetle is seen in the vineyard.

Since the emergence of the beetles from the soil is governed largely by weather conditions, especially those of temperature, no definite date for making the first application can be given. For instance, the records of Felt and Slingerland show that in normal seasons the beetles commence to appear during the last week or ten days in June, whereas, in 1907, none was found in vineyards by the writer until July 15, although he had spent a large portion of every day in the vineyards for a week or two preceding that date. Hence, it is very necessary to watch the development of the larvæ and pupæ in the soil.

The emergence of the beetles in our breeding cages during the past season coincides very closely with the appearance of the beetles in vineyards. The first two beetles appeared in the cages on the morning of July 14; by the 15th a large number had emerged, and the same day the beetles were very numerous on foliage in vineyards on gravel soil. Nearly 50 per cent of the beetles which matured from 750 larvæ, placed in the soil in our breeding cages, emerged on the third and fourth days after the first beetle appeared. This simultaneous emergence of so large a percentage of beetles shows the necessity of having the first spray application upon the vines by the time the first beetles appear, or, at least, to have the spraying equipment in readiness so that the application may be made with the least possible delay.

The time of emergence of the beetles can be determined quite closely by examining the condition of the pupæ in the soil every few days

during the latter part of June; or, still better, by collecting a hundred or so full-grown larvæ about the last of May and placing them in a shallow box, the bottom of which consists of a pane of glass, the box containing about 3 inches of moist soil. Some of the larvæ will go through the soil to the glass surface, where their transformations may be watched and the time of emergence definitely determined.

In making the spray applications care should be taken to cover all parts of the foliage. For thorough work, 100 gallons of liquid spray per acre is necessary and a pressure of not less than 100 pounds should be maintained. Two such thorough applications—one as the beetles emerge, and another not more than a week later—judging from the results obtained in our work of the past season, will prove sufficient to reduce the infestation of this insect to a point where it will not seriously affect the vitality of the vines.

The formula used in our experiments during the past season is the Bordeaux mixture formula, recommended by the Bureau of Plant Industry for combating the black rot of the grape, to which was added 3 pounds of arsenate of lead, the latter ingredient being the insecticide.

Spray formula recommended.

Copper sulphate (bluestone or blue vitriol)	pounds	5
Fresh stone lime	do	5
Arsenate of lead	do	3
Water	gallons	50

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

DEMONSTRATION SPRAYING FOR THE CODLING MOTH.

INTRODUCTION.

By A. L. Quaintance,

In Charge of Deciduous Fruit Insect Investigations.

Although the codling moth (*Carpocapsa pomonella* L.) has received a large amount of attention from entomologists, horticulturists, and others during the past fifteen or twenty years, and methods for its satisfactory control have long been known and practiced by orchardists, it is nevertheless true that a large number of apple growers either do not spray for this insect or, from lack of thorough and timely applications, do not secure satisfactory results. In connection with other work at some of the field stations in the deciduous fruit insect investigations of the Bureau of Entomology, it has been possible to make demonstration sprayings in the control of the codling moth to serve as object lessons for the orchardists of the neighborhood. The usefulness of the work is shown by its popularity among fruit growers, and indicates that, in general, work of this character is perhaps as much needed as work along purely investigative lines.

DEMONSTRATION SPRAYING IN VIRGINIA IN 1907.

By S. W. Foster.

The orchard of Mr. J. J. McHenry, where this demonstration was made, is located near the foot of the Blue Ridge Mountains near Afton, in Nelson County. This orchard site is very favorable, having a northern exposure with an elevation of about 1,000 feet, and being partly protected on the western side by a mixed forest.

Mr. McHenry's orchard consists of about 400 Yellow Newtown Pippin trees and 220 trees of the Winesap, Limbertwig, and Shockley varieties, all of which were reported to be 28 years of age. Some years ago this orchard was very profitable, but the prevalence of the codling moth, together with some of the more important fungous diseases, as bitter rot and apple scab, soon reduced and practically cut off all profits. Along with this the orchard for some time received little or no attention, and only within the last two or three years had there been any attempt toward spraying and the giving

of systematic care. But for various reasons, principally that of neglecting to apply sprays at proper times and in a thorough manner, the results had been very unsatisfactory. The work herewith reported, and carried out in cooperation with Mr. W. M. Scott, of the Bureau of Plant Industry, included the entire orchard and was designed to give freedom from the codling moth and fungous diseases as well. The entire orchard was sprayed except a few trees for purposes of comparison.

Location of unsprayed trees used in determining results.—The unsprayed trees used for counts of fruit in this demonstration were selected just prior to the first spraying. With two exceptions the trees were in each of two rows running through the middle of the orchard, five rows apart. Two pippin trees (one to be sprayed and one to be left unsprayed) were also selected near the edge of the orchard for possible comparison with other treated and untreated trees.

Treatment.—As bitter rot and apple scab had in previous years caused serious injury to the fruit in this orchard, a treatment was planned to control both insects and fungous diseases, namely, the application of Bordeaux mixture with an arsenical added. Six applications of Bordeaux mixture were made, using for the first application 4 pounds of bluestone and 6 pounds of quicklime to 50 gallons of water, and for the subsequent applications 5 pounds of bluestone and 5 pounds of quicklime to 50 gallons of water. Arsenate of lead, 2 pounds to 50 gallons of the mixture, was used with the first, second, and fifth applications.

Times of application.—The first application (4–6–50 formula of Bordeaux mixture plus 2 pounds arsenate of lead) was applied just after the blossoms fell, to fill the calyx cavities of the apples with poison, and, owing to continued unfavorable weather, was very much prolonged, from April 30 to May 9. The second application was made three weeks later, about the time it was thought that the moths from the over-wintering larvæ would begin to deposit eggs in numbers, that is, from May 21 to 27; the third application, five weeks later, June 24 to 26; the fourth, July 10 to 13. The fifth, containing arsenate of lead, for the second brood of larvæ, was applied soon after the first adults began to emerge from the cocoons of the first-brood larvæ, July 25 to 29. The sixth, being the last, was a treatment with Bordeaux mixture alone, and was applied from August 12 to 15.

The outfit used consisted of a large hand pump with two horizontal cylinders mounted on a 200-gallon tank, and two leads of hose with 15-foot extension rods, with double Vermorel nozzles. A platform elevated about 4 feet over the rear end of the tank proved very advantageous, especially for the first application, as it enabled

one man to cover the tops of the trees completely and direct the spray downward.

Results.—The following tables show the comparative results from sprayed and unsprayed trees:

TABLE I.—*Comparison of sound and wormy fruit from 5 sprayed and 5 unsprayed trees, Winesap variety, McHenry orchard, Afton, Va., 1907.*

Date of spraying and tree number.	Total crop.	Windfalls.			Fruit from tree.			Total wormy.	Total not wormy.	Total number of apples.	Per cent sound fruit.
		Wormy.	Not wormy.	Total.	Wormy.	Not wormy.	Total.				
Sprayed Apr. 30, May 21, June 24, July 10, July 25, Aug. 12.	*Bushels.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	
Tree 1	19.25	37	168	205	217	4,008	4,225	254	4,176	4,430	94.26
Tree 2	11.75	26	180	206	165	2,567	2,732	191	2,747	2,938	93.50
Tree 3	12.75	42	126	168	97	2,631	2,728	139	2,757	2,896	95.20
Tree 4	8.25	43	172	215	36	1,670	1,706	79	1,842	1,921	95.88
Tree 5	11.00	56	180	236	87	2,155	2,242	143	2,335	2,478	94.23
Trees 1 to 5 combined	63.00	204	826	1,030	602	13,031	13,633	806	13,857	13,663	94.50
Unsprayed:											
Check A	7.00	715	54	769	531	318	849	1,246	372	1,618	22.99
Check B	9.25	1,255	115	1,370	521	291	812	1,776	406	2,182	18.60
Check C	5.50	455	53	508	419	309	728	874	362	1,236	29.28
Check D	5.00	532	85	617	307	196	503	839	281	1,120	25.08
Check E	5.50	660	62	722	475	201	676	1,135	263	1,398	18.81
A, B, C, D, E, combined	32.25	3,617	369	3,986	2,253	1,315	3,568	5,870	1,684	7,554	22.29

Table I shows an average of 94.50 per cent of fruit not wormy from the sprayed trees against 22.29 per cent of fruit not wormy from the unsprayed trees. This is a saving of 72.21 per cent of the crop in favor of sprayed trees.

TABLE II.—*Comparison of sound and wormy fruit from 5 sprayed and 5 unsprayed trees, Newtown (Albemarle) Pippin variety, McHenry Orchard, Afton, Va., 1907.*

Date of spraying and tree number.	Total crop.	Windfalls.			Fruit from tree.			Total wormy.	Total not wormy.	Total number of apples.	Per cent sound fruit.
		Wormy.	Not wormy.	Total.	Wormy.	Not wormy.	Total.				
Sprayed Apr. 30, May 21, June 24, July 10, July 25, Aug. 12:	*Bushels.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	
Tree 1	14.25	28	392	420	49	3,044	3,093	77	3,436	3,513	97.81
Tree 2	13.75	53	473	526	31	2,355	2,386	84	2,828	2,912	97.11
Tree 3	13.75	42	447	489	114	2,160	2,274	156	2,607	2,763	94.36
Tree 4	21.25	124	608	732	164	3,186	3,350	288	3,794	4,082	92.95
Tree 5	18.00	116	1,010	1,126	192	2,653	2,845	308	3,663	3,971	92.24
Trees 1 to 5 combined	81.00	363	2,930	3,293	550	13,398	13,948	913	16,328	17,241	94.70
Unsprayed:											
Check A	23.50	1,504	611	2,115	2,240	1,089	3,329	3,744	1,700	5,444	31.22
Check B	12.00	929	316	1,245	980	389	1,369	1,909	705	2,614	26.96
Check C	11.00	1,380	129	1,509	444	166	610	1,824	295	2,119	13.92
Check D	9.50	1,348	89	1,437	372	126	498	1,720	215	1,935	11.11
Check E	12.00	536	353	889	1,604	26	1,630	2,140	379	2,519	15.04
A, B, C, D, E, combined	68.00	5,697	1,498	7,195	5,640	1,796	7,436	11,337	3,294	14,631	22.51

The five sprayed trees show an average of 94.70 per cent of fruit not wormy as against 22.51 per cent, the average percentage of fruit not wormy from the unsprayed trees. This is a saving of 72.19 per cent of the crop for the treated trees.

Leaving out the wear of apparatus, such as pump, wagon, etc., the cost of the six applications for the entire orchard is given as follows: Two men 22½ days at $1.25 per day, $56.25; 2 men 22½ days at $1 per day, $45; 2 horses 22½ days at $1 per day, $45, making a total cost for labor of $146.25.

For the 620 trees, 14,100 gallons of spray were required, the material costing as follows: Arsenate of lead, 324 pounds at $0.125 per pound, $40.50; copper sulphate, 1,260 pounds at $0.08¾ per pound, $110.25; lime, 11 barrels at $0.80 per barrel, $8.80, making a total cost for material and labor of $305.80, or an average cost for all spraying of 49 cents per tree.

The 5 sprayed Winesap trees gave a yield of 18 barrels of No. 1 apples, 1 barrel of No. 2's, and one-half barrel of culls. The price received for these grades of red fruit was $3.25, $2, and $1.75, respectively, per barrel. This gives a total receipt of $61.35 for the 5 sprayed trees or $12.27 per tree. This, minus 49 cents, the cost of spraying, leaves a net return of $11.78 per tree. The yield of the 5 unsprayed trees was 1¼ barrels of No. 1 apples, 1 barrel of No. 2's, and 3 barrels of culls, giving a total return of $11.31 for the 5 trees, or $2.26 per tree, leaving a difference of $9.25 as a net gain per tree in favor of the sprayed trees.

The net gain was even more favorable with the Yellow Newtown Pippin variety, the 5 sprayed trees yielding 20½ barrels of No. 1 apples, 1 barrel of No. 2's, and one-half barrel of culls. The prices received for these grades of this variety were $4.25, $3, and $1.75, respectively, per barrel, giving a total of $90.97 for the 5 trees, or $18.19 per tree. This, minus 49 cents, the cost of spraying, leaves a net return of $17.70 per tree. The 5 unsprayed trees gave only 1¾ barrels of No. 1 apples, 3 barrels of No. 2's, and 7½ barrels of culls; at the same price this gives a total of $29.12 for the fruit from the 5 unsprayed trees, or $5.82 per tree, leaving a difference for the sprayed trees of $11.88 net gain per tree.

DEMONSTRATION SPRAYING IN PENNSYLVANIA IN 1907.

By Fred Johnson.

The apple orchard used in this demonstration is situated on a high bluff along the shore of Lake Erie about a mile north of the village of North East, Pa. It is bounded on three sides by steep banks, with woods on the north and east, and open on the south

and west. There are about 250 trees in the orchard, consisting mainly of Baldwins, with several rows of Greenings on the north side which were not used in the work. The trees are about 30 years old; most of them about 25 feet high, with corresponding spread of limbs.

Previous to the spring of 1907 the orchard had been in sod for many years, and no pruning had been done for a like period. The orchard was kept under observation during the summer of 1906, and the condition of the fruit at harvest time was carefully noted. Under the management to which the orchard had been subjected for many years, the grass had been cut for hay, no spraying had been done, and no fruit had been picked from the trees, although in 1906 the ground beneath a large number of them was covered with fallen fruit, indicating that a fair crop of fruit had set. Some of this fruit was picked up and sold at $0.17 per hundredweight for cider-making purposes. Practically all of this fruit was injured by the codling moth and the plum curculio.

On September 5, 1906, a Baldwin tree was selected as fairly representing the condition of the trees in the orchard, and all of the fruit then on the ground was picked up and classified as to injury by codling moth and plum curculio, and all fruit which fell to the ground after this date, and that picked at harvest time, was likewise classified.

The total picked and dropped fruit, amounting in all to 2,766 apples, showed 95.62 per cent injury by the codling moth, and 62.55 per cent bearing egg and feeding punctures of the plum curculio.

The owner of the orchard, at the suggestion of the writer, decided to prune and cultivate the orchard in 1907, and it was placed at the disposal of the Bureau of Entomology for spraying experiments. The trees were pruned very early in the spring and the sod broken up and cultivated twice later in the summer. One hundred and fifty trees, all Baldwins, with the exception of a few scattered Astrachans, were laid out into 15-tree plats, including a check plat, and treated with Bordeaux mixture and an arsenical in a way to ascertain the value of applications at different dates. One of these plats received the usual "demonstration" treatment for that latitude, and it is from this plat and the check plat that the data to be given were obtained.

Three applications of spray were made: (First) June 10, immediately after petals fell; (second) July 2, three weeks later, when first eggs of codling moth were being deposited; (third) August 9, when adults were beginning to emerge and to deposit eggs for the second brood. The 5–5–3–50 formula was used—that is, 5 pounds copper sulphate, 5 pounds stone lime, 3 pounds arsenate of lead, and 50 gallons of water.

The applications were made with a gasoline-power sprayer mounted on low trucks, with a 4-foot derrick, using 10-foot bamboo rods and double nozzles. In the operation of spraying a pressure of about 100 pounds was maintained and between 4 and 5 gallons of liquid were used per tree at each application.

The sprayed trees were separated from the untreated check trees by two rows of trees which were also sprayed to act as a barrier and to prevent the overflow of codling moth which might breed on the unsprayed plat during the summer.

Table III gives the results obtained from three trees in both the sprayed and unsprayed plats, by actual count and examination of windfalls and picked fruit.

TABLE III.—*Comparison of sound and wormy fruit from 3 sprayed and 3 unsprayed trees, Baldwin variety, Sprague Orchard, North East, Pa., 1907.*

Dates of spraying and tree number.	Total crop.	Windfalls.			Fruit from tree.			Total wormy.	Total not wormy.	Total crop.	Per cent sound fruit.
		Wormy.	Not wormy.	Total.	Wormy.	Not wormy.	Total.				
Sprayed June 10, July 2, and August 9:	*Bushels.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	
Tree No. 1	9.25	22	235	257	19	2,151	2,170	41	2,386	2,427	98.31
Tree No. 2	5.50	74	264	338	17	1,279	1,296	91	1,543	1,634	94.43
Tree No. 3	5.50	76	281	357	26	1,099	1,125	102	1,380	1,482	93.12
Trees Nos. 1 to 3 combined	20.25	172	780	952	62	4,529	4,591	234	5,309	5,543	95.78
Unsprayed:											
Check A	3.00	324	34	358	547	90	637	871	124	995	12.46
Check B	3.75	559	262	821	303	237	540	862	499	1,361	36.66
Check C	5.25	599	255	854	626	222	848	1,225	477	1,702	28.03
Checks A to C combined	12.00	1,482	551	2,033	1,476	549	2,025	2,958	1,100	4,058	27.11

Table IV gives the yield of windfalls and picked fruit in bushels and its market value for 14 trees in the sprayed plat and for the same number of trees in the unsprayed plat.

TABLE IV.—*Comparison of yield and character of fruit from 14 sprayed and 14 unsprayed trees, Baldwin variety, Sprague Orchard, North East, Pa., 1907, with value of crop.*

Date of spraying.	No. of trees.	First-class apples.	Second class apples.	Canners.	Ciders.	Total.	Value first class.	Value second class.	Value canners.	Value ciders.	Total value.
		Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Dolls.*	*Dolls.*	*Dolls.*	*Dolls.*	*Dolls.*
June 10, July 2, and August 9	14	43.25	20.25	4	20.75	88.25	43.25	13.50	1.20	3.10	61.05
Unsprayed checks	14	.....	.....	22	58.00	80.00	.....	.....	6.60	8.70	15.30

The picked fruit was packed in two grades, the first grade bringing $3 per barrel, the second grade $2 per barrel. The windfalls and

culls were also sorted into two grades. Those above 2 inches were used for canning and sold for 60 cents per hundredweight, while those of the smaller grade were used for cider-making purposes and sold for 30 cents per hundredweight.

The total amount of spray applied to the 14 trees was 182 gallons, about 13 gallons per tree for the three applications, at a cost of about 2 cents per gallon, or $3.64 for the 14 trees.

The time required to make the applications was about one and one-half hours for each time, or about four and one-half hours for the three applications.

Two men and a team were used in the work, and the wage paid was 40 cents per hour for man and team, and 17.5 cents per hour for the additional man, making the cost of labor $2.59 for the four and one-half hours, the total cost of labor and material being $6.23. Allowing $1 for gasoline and wear and tear on the machine, there was a total expenditure of $7.23. Deducting this amount, together with $15.30 (the value of the crop from the untreated check plat), from $61.05 (the value of the crop from the sprayed plat), there is a net gain of $38.52 on the 14 trees, or $2.75 per tree for the sprayed trees.

DEMONSTRATION SPRAYING IN OHIO IN 1907.

By A. A. Girault.

An orchard belonging to Mr. A. P. Roudebush, a prominent farmer and fruit grower of Owensville, Clermont County, Ohio, and one of the largest in that vicinity, was selected for this spraying demonstration against the codling moth. This orchard consisted of about 400 trees of such well-known varieties as Ben Davis, Rome Beauty, Grimes Golden, etc. The orchard was in sod; the trees were vigorous, from about 25 to 30 feet tall, and well shaped, but needed thinning. During the past two or three years they had been treated with not more than two applications of Bordeaux mixture and arsenate of lead. The codling moth was a well-established pest in this orchard, and the owner was discouraged over the difficulties which he had encountered in combating it.

The plat selected for this work consisted of a single row of 27 Ben Davis trees, 10 years of age, in the southwestern portion of the orchard, and adjoining an orchard of young trees; in the center of the next row to the northeast 10 trees of similar variety and age were left untreated for purposes of comparison. Four applications of Bordeaux mixture and an arsenical were made, using 5 pounds of lime, 5 pounds of bluestone, 2 pounds of arsenate of lead, and 50 gallons of water. Spraying was done on the following dates: May 10,

June 14, July 25–26, and August 15. The table below shows the results, as determined from 5 sprayed and 5 unsprayed trees in each plat:

TABLE V.—*Comparison of sound and wormy fruit from 5 sprayed and 5 unsprayed trees, Ben Davis variety, Roudebush Orchard, Owensville, Ohio, 1907.*

Date of spraying and number of trees.	Total crop.	Windfalls.			Fruit from tree.			Total wormy.	Total not wormy.	Total crop.	Per cent sound fruit.
		Wormy.	Not wormy.	Total.	Wormy.	Not wormy.	Total.				
Sprayed May 10, June 14, July 25, and August 15: Trees 1 to 5 combined.....	*Bushels.* 9.80	*No.* 78	*No.* 1,997	*No.* 2,075	*No.* 121	*No.* 1,571	*No.* 1,692	*No.* 199	*No.* 3,568	*No.* 3,767	94.72
Unsprayed: Checks A to E combined.....	3.25	1,992	2,218	4,210	651	68	719	2,643	2,286	4,929	46.38

The tabulated results show that the four applications gave about 94 per cent fruit free from codling moth injury and trebled the yield in bushels, while the total marketable crop in bushels was more than twice doubled. In the checks the percentage of wormy fruit in the total yield was 46.38 per cent, whereas in the sprayed trees it was but 5.28 per cent. The contrast between the treated and untreated trees at harvest time was marked, even to the casual eye, because the latter had been partly defoliated by various leaf-feeding insects, and the attack of the codling moth and plum curculio had been disastrous to the fruit yet remaining; whereas the foliage and fruit of treated trees were in almost perfect condition. The four treatments also prevented over 50 per cent of the injury of the plum curculio, which is a more serious enemy of apples in this vicinity than is the codling moth.

The four applications required 450 gallons of the mixture at a cost of $0.016 per gallon, a total cost of $7.20 for the Bordeaux mixture and poison. Adding the cost of labor for 2 men at $1.50 per day and a team at $2 per day for one and one-half days, which is $7.50, the cost of the whole operation was $14.70, or at the rate of $0.54 per tree. Placing the price of apples per bushel at $1, the net returns from a single unsprayed tree would be about 36 cents, whereas the net returns from a single sprayed tree would be $1.31, a net gain of about 95 cents per tree. As will be seen from the table, the crop in this orchard was quite light. With a normal crop the percentage of benefit would have been much larger.

U. S. D. A., B. E. Bul. 68, Part VIII. D. F. I. I., January 20, 1909.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE GRAPE-LEAF SKELETONIZER.

(*Harrisina americana* Guérin-Méneville.)

By P. R. Jones,
Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

For the last sixty years or more the species known as *Harrisina americana* has been brought to the attention of entomologists and vineyardists by the characteristic feeding of the yellowish, black-spotted larvæ in soldierlike rows upon the foliage of the grape. As this is the only Lepidopterous insect that feeds in a gregarious manner upon grape foliage it will be easily recognized. Although it has been known for a number of years, many points have been lacking in the knowledge of its life history and habits, and it is hoped that the following pages will present some facts that hitherto have not been mentioned, as well as give a summary of what has been learned about the insect up to the present time.

HISTORY.

There is considerable doubt as to where this insect was first figured and described. In G. Henderson's edition of the Animal Kingdom it is figured by Baron Cuvier (1837) under the name *Agloape americana* Boisduval, but no description is given. A description and figure are published by Guérin-Méneville, the insect being listed as *Agloape americana* Boisduval. The dates of issue in the latter case (1829–1838) are evidently erroneous, as there are in the volume frequent references to articles published in 1840, 1841, and some as late as 1843; the volume was, therefore, probably not issued before 1844 or 1845. Harris, in 1839, described the species as *Procris americana* and figured its various stages. This appears to be the first published

description, as Harris says in a note after the description: "This insect appears to be the same as the one figured in Guerin's Iconographie and Griffith's Cuvier, under the name of *Agloape americana* Boisduval, but it is not an Agloape, for it has a distinct spirally-rolled tongue." He makes no mention of a description and apparently had not seen any. The specific name should be attributed to Guérin-Méneville, as he is the author of the book in which the figure first appeared, and because he does not at any place give specific credit to Boisduval, who undoubtedly described it.

The first economic account of the insect appears in Hovey's Magazine of Horticulture for June, 1844, where Harris, under the name *Procris americana*, gives a full account of its relation to European species, its natural food plants, life history, and habits. He mentions it as first brought to his notice in 1830 by Professor Hentz, who found larvæ upon a vine at Chapel Hill, in North Carolina.

In 1855 Townend Glover reports it as injurious in the vicinity of Washington, D. C., and gives a short general account.

Harris, in 1862, gives an account of it which is practically the same as the one which appears in Hovey's Magazine, but shorter.

Walsh (1866) next determines the insect and gives a short account of it, in answer to a letter.

In 1867 C. V. Riley gives a brief account, with notes on its life history and habits. Bethune then (1867) published a short general account of it.

In 1869 Walsh and Riley determined some insects to be *Procris americana* Boisduval. Riley (1870) gives the most detailed account published up to the present date and treats of its identity, food plants, life history and habits, natural enemies, and remedies. During the same year he again writes concerning it, but the account is taken from the previous one.

Lintner (1879) gives a short general account and again (1883) mentions it in answer to a letter. The next account of it is a short account by Atkinson, in 1888.

Neal, in 1890, presents most of the knowledge up to the present date and records some original observations as to the number of broods and varieties of grapes preferred.

Toumey (1893) records it from two localities in Arizona and gives a short review of its manner of working.

J. B. Smith (1895) next writes concerning it and gives a detailed account of its life history and habits, with some new points on local distribution. During the same year (1895) Slingerland reviews the chief points in its life history in answer to a letter.

Starnes (1898) gives a general account of it and mentions the fact of its being more prevalent in the West and South than in the East.

The latest economic reference is that of J. B. Smith (1903), who figures it as one of the insects sometimes troubling grapes.

ORIGIN AND DISTRIBUTION.

The grape-leaf skeletonizer is probably a native species, from the fact that it feeds upon Virginia creeper and wild grapes in addition to the domestic varieties of grape. Harris mentions it as related to *Procris ampelophaga*, of Europe, which is injurious to the vineyards of Piedmont and Tuscany, and Riley states that it is related to the European *Procris vitis*.

In literature it has been recorded from the following States and Provinces: Canada (Bethune); New England (Walsh); New York (Slingerland); New Jersey (Smith); Washington, D. C. (Glover); North Carolina (Walsh); Georgia (Starnes); Florida (Neal); Ohio (Lintner); Missouri (Riley); and Arizona (Toumey).

In the files of the Bureau of Entomology there are records as follows: Orange, N. J.; Dalton, Philadelphia, and Williamsport, Pa.; Berwyn, Cambridge, Sharptown, and Sullivan, Md.; Washington, D. C.; Afton, Va.; French Creek and Lewisburg, W. Va.; Raleigh, N. C.; Columbia and Timmonsville, S. C.; Poulan, Ga.; Jacksonville, Oakland, Stephensville, and Umatilla, Fla.; Auburn, Ala.; Masengale and Poplarville, Miss.; Mandeville and New Orleans, La., and Hermosillo, Mexico.

FOOD PLANTS AND DESTRUCTIVENESS.

Harris states that this species feeds very readily upon *Ampelopsis quinquefolia;* Riley writes that its natural food is Virginia creeper and wild grapes; while both record it as being fond of cultivated grapes. Toumey states that it was found upon *Vitis arizonica*, and Neal records it as living naturally upon wild grapes and Virginia creeper but that it prefers cultivated grapes, especially if exotic or choice. Riley mentions that a Mr. Jordan, of St. Louis, Mo., states that it attacks Concords but never the Clinton or Taylor varieties in his vineyards. During the past summer the writer noticed that it was especially fond of certain hothouse varieties in an abandoned greenhouse upon the Department grounds.

CHARACTER OF INJURY.

The young larvæ during the first three or four instars feed only on the outer epidermal layer of the leaf, completely skeletonizing it. (See fig. 12.) This is done on both the upper and lower surfaces; according to the writer's observation there is preference for the up-

per surface, but several entomologists record the lower surface as being preferred. Later the larvæ, which until now have fed in a

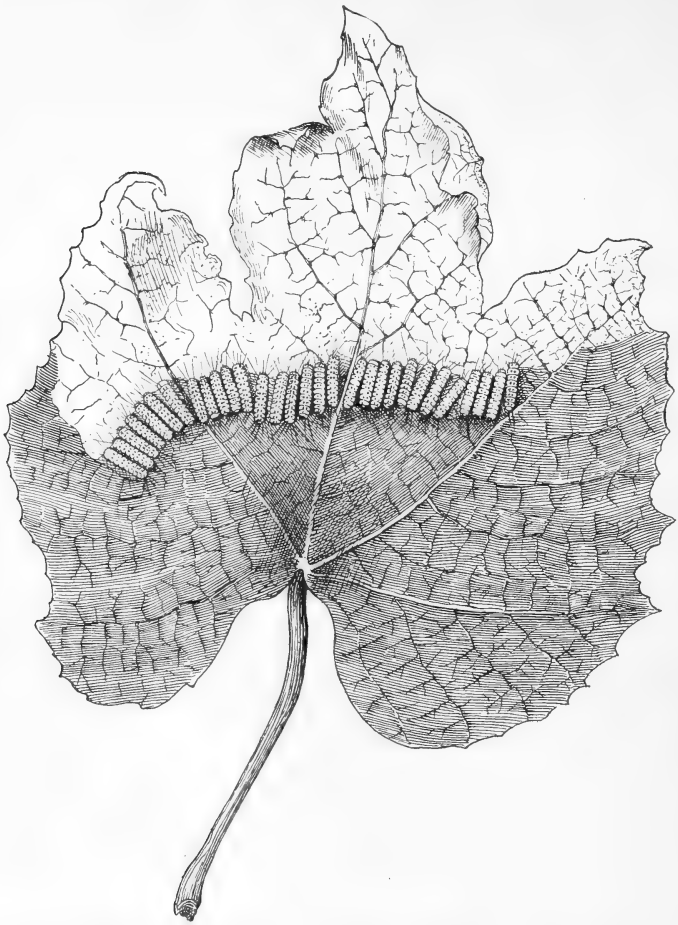


FIG. 12.—The grape-leaf skeletonizer (*Harrisina americana*): Young larvæ feeding on leaf. (Original.)

row side by side, separate into single individuals or into small groups and eat the whole tissue of the leaf except the larger veins.

DESCRIPTION.

EGG.

The egg (fig. 13) is small, shining, dilute lemon-yellow in color, cylindrical-oval or capsule shaped, with an irregular hexagonal sculpturing. From a number of eggs measured the maximum length is 0.600 mm. and the minimum 0.533 mm.; the maximum width is 0.383

mm. and the minimum 0.316 mm. The average size of the egg is 0.566 mm. by 0.349 mm.

The eggs are deposited on the underside of the leaves in clusters, and from 12 clusters counted, the minimum contained 7 eggs, the maximum 260, the average cluster containing 107.9 eggs. Observations on 1,035 eggs gave the average length for the egg stage as 7.92 days, with a maximum of 9 days and a minimum of 7 days, the average mean temperature for the period of incubation of the various eggs being 77.5° F., with cloudy weather prevailing. The eggs under observation were from the second generation of moths, and the length of the stage would probably be somewhat greater for the first generation on account of lower temperature.

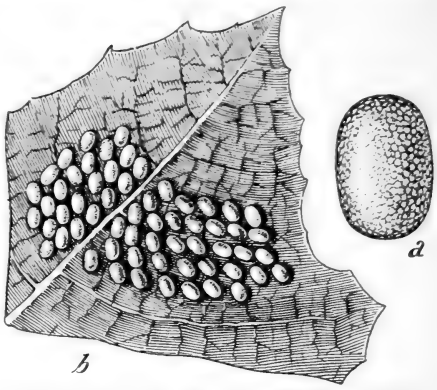


FIG. 13.—The grape-leaf skeletonizer (*Harrisina americana*): *a*, Egg, greatly enlarged; *b*, cluster of eggs in natural position on leaf. (Original.)

LARVA.

First instar.—Body yellowish-white, translucent. Head similar in color to body, retractile, broader than body, which gradually tapers. Segments 2–13 with a transverse median row of spinelike bristles, about 0.2 mm. in length, extending to venter on each side; whitish when viewed under a ⅔-inch objective, but the dark-colored joints cause them to appear blackish under a small magnification. Thoracic feet small, pointed, color similar to body; abdominal feet small, visible only as small wartlike protuberances. Length, 1–1.25 mm.; width of head, 0.18–0.25 mm. (variable).

Second instar.—Body dilute-yellow, head retractile, darker, eyes and mandibles dark brown. Tubercular areas now distinct under a ⅔-inch objective as a transverse row of wartlike clusters of whitish, segmented bristles about 0.2 mm. in length, with apex, joints, and bulb at base of the bristles black. All the segments laterally, and dorsum of the anterior and posterior segments with long, whitish, segmented hairs about 0.75 mm. in length. Thoracic feet small, pointed, dilute-brownish; abdominal feet, more distinct now, appearing as small stumplike projections. Length, 1.666–2 mm.; width of head, 0.283–0.333 mm.

Third instar.—Body orange-yellow, head retractile, dilute-brown, eyes and mandibles brownish-black. Segments 2–13 show wartlike

tubercles, with bristles similar to those in the preceding instar, 0.2–0.25 mm. in length, with the black on the apices, joints, and bulbs at the base more pronounced, causing the tubercles to appear black to the naked eye. All the segments laterally, and dorsum of the anterior and posterior segments with long, segmented, whitish hairs variable in length. Thoracic feet small, pointed, dilute-brown, darker at the tip; abdominal feet larger, apex with a circlet of black bristles, all the feet similar in color to the rest of the body. Length, 3.5–4.5 mm.; width of head, 0.666 mm. (nearly constant).

Fourth instar.—Body sulphur-yellow, head retractile, dilute-brown, darker on exposed portion, mandibles and eyes brownish-black. Head when viewed from above oval-pyramidal in form. Tubercular areas very prominent now to naked eye, appearing as black, bristly, wartlike patches, this appearance due to the black tips of the whitish, jointed bristles; joints and bulbs at base of bristles blackish. Tubercular areas on dorsum of segments 7, 8, 9, and more especially 7 and 9, fainter to naked eye than on other segments, as the bristles are not so heavily tipped with black nor are the joints black. Dorsum of anterior and posterior segments and all segments laterally with long, whitish, segmented hairs of variable length. Thoracic and abdominal feet yellowish, longer, but marked the same as in the third instar. Length, 7–8 mm.; width of head, 1.05–1.06 mm. (nearly constant).

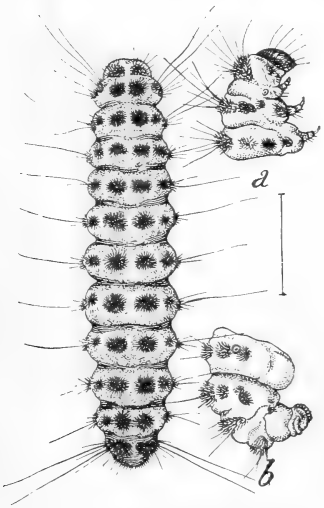


FIG. 14.—The grape-leaf skeletonizer (*Harrisina americana*): Full-grown larva, at left; *a*, lateral view of head and prothoracic segments; *b*, lateral view of posterior segments. Enlarged. (Original.)

Fifth instar.—Body deep sulphur-yellow, head retractile, dilute-brown, darker on exposed portion, mandibles and eyes brownish-black. Shape of head similar to that in the fourth instar. Tubercular areas now very prominent to naked eye and appearing as black, bristly, wartlike patches. Bristles under $\frac{2}{3}$-inch objective same as in the fourth instar, but more distinct and longer (0.20–0.33) mm. in length). Tubercular areas distinct on all segments, and to naked eye with a slight opaque-bluish cast. Dorsum of anterior and posterior segments, and all segments laterally, with long, segmented, whitish hairs, longer than in fourth instar. Thoracic feet yellow, tipped with black; abdominal feet yellow, with a terminal circle of black bristles. Length, 8–10 mm.; width of head, 1.15–1.45 mm. (variable).

Sixth instar (full-grown larva) (fig. 14).—Cylindrical and uniform in shape, color deep sulphur-yellow. Head oval-pyramidal in form, dark brown, lighter above, retractile, concealed beneath first prothoracic segment. Mandibles and maxillæ dark brown, maxillary palpi yellow, translucent, eyes black. Tubercles flat, wartlike areas, appearing to naked eye as a transverse, median row of black dots. Under a ⅔-inch objective, tubercles wartlike, covered with short, thick, segmented, white bristles tipped with black, joints and bulb at base of bristles dark colored (length, 0.20–0.33 mm.). Tubercles arranged: I, subdorsal; II and III, lateral; III, just above spiracle; IV, substigmatal; V, above base of leg. Subdorsal tubercles confluent on segment 2. Segments 5–14 with tubercle III wanting, segments 7–14 with tubercle V wanting, subdorsal and lateral tubercles confluent on segment 13, subdorsal tubercle confluent on segment 14, the rest wanting. Anterior and posterior segments dorsally and all segments laterally with a number of long, whitish, segmented hairs, variable in length. Spiracles round, light brown, present on first prothoracic and on all abdominal segments except anal, the one on segment 13 smaller than the rest. Thoracic feet translucent, yellow, small, pointed, with a single black claw at tip and also a few light-colored hairs on sides. Abdominal feet pale yellow, apex with a row of small, black, bristlelike claws. Length, 11–13.5 mm.; width of head, 1.483–1.666 mm. (variable).

FIG. 15.—The grape-leaf skeletonizer (*Harrisina americana*): Cocoon. Enlarged. (Original.)

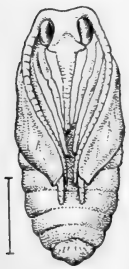


FIG. 16.—The grape-leaf skeletonizer (*Harrisina americana*): Pupa. Enlarged. (Original.)

COCOON.

Cocoon (fig. 15) flat, oblong-oval in shape, composed of a tough, white, cottony, parchmentlike material, opaque when dry, but showing pupa underneath when wet. Length, 10–12 mm.; width, 5 mm.

PUPA.

Pupa (fig. 16) uniformly orange-colored in fresh specimens, brown in older ones; oblong-oval, broadest at abdominal segments 3, 4, and 5. Eyes and spiracles darker than rest of body. Spiracles raised wartlike projections, subconical in shape, eight pairs, the eighth pair the longest. Spiracles arranged on latero-dorsal aspect of abdominal segments 2–9. Ante-

rior third of dorsum of abdominal segments 3–8 covered with very short, decumbent black bristles, the row not extending quite as far as the spiracles on either side. Cremaster wanting, replaced by six very short black bristles which are nearly obsolete in some specimens and appear as black dots. Bristles arranged on the submedio-dorsal aspect of the anal segment as two median pairs and one lateral bristle on the outside of the median pairs. Wing sheaths, and leg sheaths of first pair of legs, subequal, antennal sheaths longer, all extending to about fifth abdominal segment, those of third pair of legs projecting slightly beyond. Length, 6–9 mm.

Observations upon a number of pupæ during the month of July, 1908, in Washington, D. C., show the minimum length of this stage to be 9 days, the maximum 12 days, while the average length for the period is 10.9 days. The average number of days spent in the cocoon is 14.8. The average mean temperature for the month of July, or the time the pupæ under observation were in the cocoons, was 78° F.

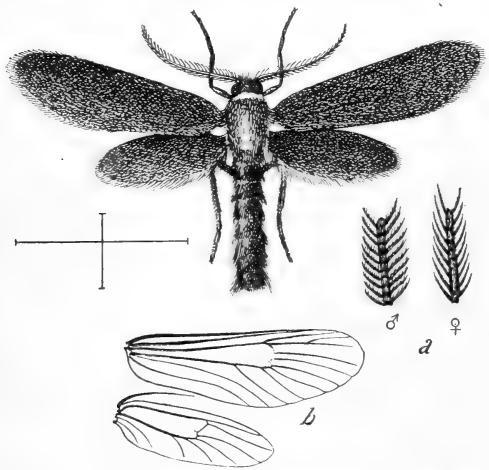


FIG. 17.—The grape-leaf skeletonizer (*Harrisina americana*): Male moth; *a*, antenna of male at left, of female at right; *b*, venation of front and hind wings. Enlarged; *a*, much enlarged. (Original.)

ADULT.

(Fig. 17.)

Uniformly blue-black, except a yellow collar which extends nearly to ventral side. Wings, legs, and eyes similar in color to rest of body. Antennæ pectinate, more so in male than in female, and plumose in male, length about five-sixteenths of an inch in male, four-sixteenths of an inch in female. Abdomen longer, more slender in male than in female and curved upward. Abdomen with a fan-shaped, somewhat bilobed caudal tuft.

Length of moth, 8–11 mm.; length of wing, 11 mm.

Expanse of wing, 22–24 mm.

The following is the original description by Harris:

Blue-black, with a saffron colored collar and a fan-shaped, somewhat bilobed, black caudal tuft. Expands from 10 lines to 1 inch.

SEASONAL HISTORY.

NUMBER OF GENERATIONS.

Former writers have generally attributed two generations and a partial third to this insect; in fact, all, with the exception of Neal, who states that there are three broods in Florida, are of the opinion that there are two broods. Extended observations and studies during the past summer reveal the fact that there are not two full generations in the vicinity of Washington, D. C. Seasonal history studies show that moths from the over-wintering pupæ appear during the latter part of May or chiefly during the first ten days of June. Eggs from these moths were found June 11, 1908, and also a few very young larvæ. By June 30 some larvæ were almost fully grown, but the majority of full-grown larvæ did not appear until about July 14, although a number of pupæ from the early-developing larvæ were found on July 7, showing a long period from the appearance of the first full-grown larvæ to the appearance of those which attained their growth at the latest date.

The second generation of moths, or those from first-generation larvæ, appeared continuously from July 18 to August 15, giving a very extended period of emergence and accounting for the tendency of former writers to attribute the late-appearing ones to a third generation.

The largest number of moths appeared from July 20 to 25. A number of those larvæ which had attained their growth by July 14 hibernated as pupæ and did not emerge as moths, thus showing clearly that there was not a full second generation.

Eggs from the second-generation moths were most numerous from July 20 to 23, with many second-generation larvæ appearing on July 27. Some of the second-generation larvæ were full-grown on August 24 and were spinning cocoons on that date and up to September 16, when all had gone into cocoons.

LIFE CYCLE.

The average length of the life cycle was found by adding together the average lengths of egg stage, larval period, time spent in cocoon, and life of moth. The average length of the egg stage was 7.92 days, the average length of the larval period 40.5 days, the average time spent in cocoon 14.8 days, and the average length of life of a moth 3.5 days; thus, the average length of the complete life cycle was found to be 66.72 days. The minimum life cycle, found by taking the minimums of the various periods and adding them together, was 53 days.

All of these averages were taken from a very large series under observation. While the above figures should not be taken and used to find how many generations there are in any given locality, they will give some clue to the time required for the development of a

generation. Temperature conditions undoubtedly influence greatly the lengths of the various life periods.

HABITS.

Late in May or in the early part of June the over-wintering pupa makes a narrow slit in one end of the cocoon and exposes a small part of the anterior portion. The pupa case then splits and the moth emerges, the operation requiring from about 15 to 20 minutes. Sometimes the wings become their normal size in a short time, but in other cases 24 hours elapsed before the moth was perfect. The moths mate on the next day, or second day following. One pair under observation, having emerged on July 22, in the night, mated early July 23, and was observed in copulation from 7.30 until 11.30, a period of 4 hours. This was probably near the normal period, as the pair had not been out of the cocoon long. Oviposition usually follows soon after. In the pair mentioned above, one cluster of 69 eggs was deposited during the night of July 23. During oviposition, which took place early in the morning, or more often in the late afternoon or evening, the moth was observed to be on the underside of a leaf with the wings at right angles to the body. The abdomen was slightly bent, and the moth seemed to be depositing the eggs in rows. The period required for the oviposition of a cluster is several hours, depending upon the size of the cluster deposited. The flight of the moths appeared to be feeble, and they were sluggish, especially on cloudy days, the period of greatest activity being on clear days at midday. The length of life of the moth is from 2 to 5 days without food, although in the case of one pair under observation the male lived from 3 to 3½ days and the female from 6 to 6½ days.

The eggs are deposited on the underside of the leaf. Upon hatching, the larvæ start feeding from a common center, moving backward, and in a short time are side by side in a soldierlike formation, the feeding line usually being a curve. Although the larvæ may feed for a short time upon the lower surface, they are more frequently found upon the upper, as this is better adapted to their style of feeding—namely, skeletonizing or removing the outer epidermal layer of the leaf. This manner of feeding is usually followed until the larvæ reach the fifth instar, when some begin to eat holes through the leaf. From now on the larvæ gradually cease skeletonizing the leaf and eat the whole tissue, leaving only the larger veins.

Preparatory to molting, the larvæ crawl to the underside of the leaf and molt in a group, with their heads in the center. After molting they feed, moving backward, and gradually form a curved line. This was observed a number of times, although the larvæ had been feeding before in different groups on the upper surface of different leaves.

When the larvæ are full grown they seek some secluded place in which to pupate, usually spinning their cocoons on fallen leaves or in trash around the vine, or, when confined, to the sides of the cage. The period covered by one group of larvæ in spinning their cocoons will vary from 1 to 2 weeks, although the time required for the formation of each individual is not more than 2 or 3 days.

The winter is passed in the cocoon, the insect being in the pupal stage.

IDENTITY.

The slight variation in appearance of the moths and the differently marked larvæ bring up the question of identity. Dyar [a] thinks there is little difference between the moths of *Harrisina americana* and those of *H. texana* which Stretch separated by the presence of another vein, because moths of both kinds were taken together in the same locality. He found, however, two kinds of larvæ, those of *H. texana* having the dorsum of joints 2–13 broadly bright-yellow, and banded between each joint with blackish and again across the middle of each, including the warts, with purple-brown. The larvæ of *Harrisina australis* were similar to those of *H. texana*. He further says, "If it were not for the two kinds of larvæ, I would not hold these three forms separate." Credit is due to Dr. H. G. Dyar, of this Bureau, for examining all of the material in the Bureau collection and for determining it all as belonging to one species, *Harrisina americana* Guér.

NATURAL ENEMIES.

Up to the present time only one parasite had been recorded from this insect, namely, the chalcidid *Perilampus platygaster* Say, which Riley mentions as being a parasite of the larva. This summer, however, the writer reared a little hymenopterous parasite which was determined by Mr. J. C. Crawford, of the U. S. National Museum, as a braconid, *Glyptapanteles* sp., and also an ichneumon, *Limneria* sp., which was reared from larvæ sent in by C. M. Streeter, Dalton, Pa.

REMEDIES.

While the insect has never proved a serious pest in large vineyards, and is usually more troublesome in gardens or back yards where there are only a few vines, it has been found sufficiently numerous at times to demand attention and remedial measures.

The gregarious feeding habit of the larvæ makes hand-picking in small areas the most efficient treatment, as one person can go over a large number of vines in a short time and destroy a very large number of the larvæ, since they will be found in large groups upon the

[a] Proceedings of the Entomological Society of Washington, Vol. V, p. 326.

leaves. This should be done as soon as the larvæ are noticed upon the foliage, as all from each cluster of eggs will then be in a single group, whereas, if the treatment be deferred until the larvæ have separated into individuals or small groups, as mentioned before in this paper, much more labor will be involved.

An arsenical treatment, applied as soon as the larvæ are in evidence, would prove effective. Two applications are necessary, one for each generation of the larvæ. The time of application will vary greatly, being early in the South and becoming later in northern States, according to the time the larvæ appear upon the grapes, which is the best standard for determining when the treatment should be applied.

The arsenical used may be either arsenate of lead, Paris green, or arsenite of lime. Arsenate of lead is preferred on account of its better sticking qualities, and also because it is less likely to injure the foliage. Three pounds of any good brand of the latter added to the ordinary Bordeaux mixture (5–5–50 formula) will make a very efficient remedy.

Since the larvæ spin their cocoons in the leaves and trash at the bottom of the vines, clean culture is to be recommended. Where clean culture is followed, and where spraying is practiced for the grape-berry moth, grape root-worm, and grape curculio, this insect need never be feared.

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U. S. D. A., B. E. Bul. 68, Part IX. D. F. I. I., February 11, 1909.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE PEACH-TREE BARKBEETLE.

(*Phlœotribus liminaris* Harr.)

By H. F. Wilson,

Engaged in Deciduous Fruit Insect Investigations.

INTRODUCTION.

By way of introduction it is perhaps necessary to give an account of the present degree of importance, from an economic standpoint, which this beetle has reached in northern Ohio. For the last four or five years this insect has been doing a great amount of injury to apparently healthy trees. The history of Scolytidæ in general shows that certain species may be present in orchards for years without doing any appreciable damage. Then, owing to favorable climatic or other conditions, they may develop in large numbers and accomplish considerable injury. Such seems to be the history of *Phlœotribus liminaris.*

The attention of Prof. H. A. Gossard, of the Ohio Agricultural Experiment Station, was called to this insect by Mr. W. H. Wright, in charge of a large farm at Lakeside, Ohio, Mr. Wright having reported to him that large blocks of peach trees in the orchard were dying from an unknown cause. Upon investigation Professor Gossard found that this orchard was seriously infested with *Phlœotribus liminaris.*

At the instance of Professor Gossard, investigation of this species was undertaken in the spring of 1908 by the Bureau of Entomology in cooperation with the Ohio Agricultural Experiment Station, and the writer, representing the Bureau, and working under the joint direction of Professors Gossard and Quaintance, was assigned to the work, with headquarters at Lakeside, Ohio. Through the courtesy of Mr. Wright a suitable building and experimental orchards were secured. All breeding cages were kept under out-of-door conditions, and as far as possible outside conditions were watched in comparison with those in the breeding cages. Data were secured on all stages of development of the insect, and the results obtained are considered fairly complete for a single season's work.

In all, 43 experiments with remedial and preventive measures were conducted during the summer, results of which are given herein. Field observations in this locality seemed to show that apparently healthy trees are attacked and, although the beetles probably do not form egg burrows in these, the loss of sap from the burrows made by the adults in the bark is sufficient to cause the trees to become very much weakened.

HISTORY.

The first published notes on this insect were made by Miss M. H. Morris, about 1849–50. At that time Miss Morris credited *Tomicus liminaris* as being the cause of "peach yellows," and so expressed her belief in several articles published in different magazines of that time, stating that the beetles were quite numerous about peach trees suffering from "peach yellows." These suggestions made by Miss Morris probably led Harris to include the insect in his treatise on "The Insects Injurious to Vegetation," published in 1852, where he briefly describes it under the name *Tomicus liminaris*, this later being changed to *Phlœotribus liminaris*. The following extract gives his description:

> There is another small barkbeetle, the *Tomicus liminaris* of my catalogue, which has been found in great numbers by Miss Morris under the bark of peach trees affected with the disease called the "yellows" and hence supposed by her to be connected with this malady. I have found it under the bark of a diseased elm, but have nothing more to offer from my own observations concerning its history, except that it completes its transformations in August and September. It is of a dark-brown color, the thorax all punctured, and the wing covers are marked with deeply punctured furrows and are beset with short hairs. It does not average one-tenth of an inch in length.

The beetle spoken of above as working in elm bark was later found by Mr. E. A. Schwarz, of this Bureau, to be *Hylesinus opaculus* Lec., he having examined the specimens used by Harris and named it the elm barkbeetle.[a] (This specimen, in Mr. Harris's collection, was called *Tomicus liminaris* and catalogued as such, as is shown by copies, taken by Doctor Hopkins, of the original notes.)[b]

For many years this insect did not become sufficiently important to demand special study, either of its life history or for the determination of remedial measures. Reference to this species has been made at different times, as in the annual reports of the entomologist of the Canadian experimental farms, and by entomologists in the

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[a] Attention is here called to Mr. Schwarz's article on p. 149, Vol. I, No. 3, Proceedings of the Entomological Society of Washington (1889), on *Hylesinus opaculus*.

[b] The genus *Phlœotribus* is being revised by Doctor Hopkins, who will discuss the synonymy and other systematic features in a bulletin of the technical series of this Bureau.

WORK OF THE PEACH-TREE BARKBEETLE (PHLŒOTRIBUS LIMINARIS).

Fig. 1.—Gum exuding through burrows made in bark of peach tree. Fig. 2.—Exit holes in bark of peach tree. (Original.

United States; and more recently experiments have been carried out by the Ontario experiment station in the district of Niagara. In looking over the past literature it is noticed that the injury done by the beetle has increased materially with the increased planting of peach and cherry, and the species has thus become one of economic importance.

Until the present season (1908) few direct measures had been taken to combat this barkbeetle, and very little, if anything, was known concerning its life history. Not until recently has it become very injurious to fruit trees, and these are limited to peach, cherry, and wild cherry. The beetles will, however, work on plum trees when confined to that food. So far but three localities have been reported as being visited with injury to any great extent, these being in the fruit district lying about Lakeside and Gypsum, Ohio; in the vicinity of Cayuga Lake, New York, and in the Niagara district, Ontario Province, Canada. The effects of the beetles' work are very serious in all trees attacked.

The peach-tree barkbeetle is a native of this country, and until cultivated trees were introduced must have held to forest trees for food and breeding places. The work of the beetle is similar to that of the fruit-tree barkbeetle (*Scolytus rugulosus* Ratz.), and there exists a marked similarity in the beetles themselves by which the two species may be easily confused.

DISTRIBUTION.

Observations and reports show the distribution, in so far as known, to be as follows: New York, Pennsylvania, Maryland, Virginia, West Virginia, Ohio, and Michigan, and from the Niagara district, Ontario Province, Canada. Field notes on this species, in the branch of forest insect investigations, Bureau of Entomology, taken by Doctor Hopkins and Mr. W. F. Fiske, indicate that the species is found throughout almost all of West Virginia, and that it occurs in North Carolina and New Hampshire.

OCCURRENCE IN OHIO.

The date of the first appearance of this insect in Ohio is in question, as it has undoubtedly been in the State for some time, although it has not done any great amount of damage until recently. Some of the orchardists stated that they had seen its work for eight or ten years, but did not know the cause. An area of about 8 or 10 miles square about Lakeside, Ohio, including the adjacent islands, is badly infested. Outside of this locality the beetles occur east and west to

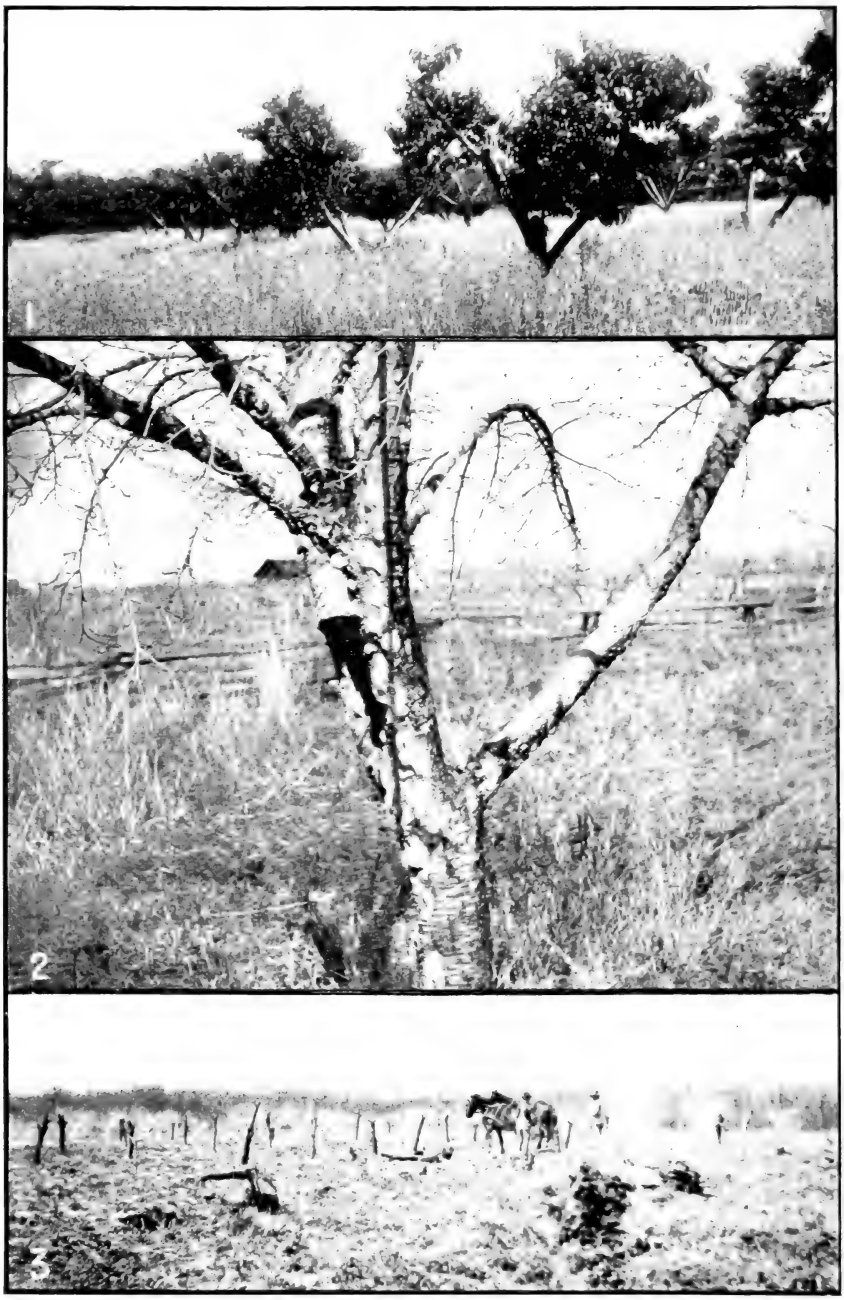
a slight degree; and as the beetles have been taken at Youngstown, Ohio, and are reported from West Virginia and Michigan, it is very probable that this species is at present more or less generally distributed throughout the State.

At Lakeside a lime manufacturing company bought up most of the land comprising the peninsula for commercial purposes. On this land are many remnants of orchards, which are uncultivated and uncared for, and are attacked by scale and numerous other insects. These trees are gradually being destroyed by the insects and are seriously attacked by *Phlœotribus liminaris*. Pieces of bark 2 to 3 feet long and extending half way around the trunk will be completely cut from a tree 8 inches in diameter by the larvæ. The dead trees in these orchards were uninfested when observed, but the bark was full of exit holes and the trees were girdled. (See Pl. XI, fig. 2.) Until these infested trees are all killed they will afford ideal breeding places for the beetles while they attack the near-by orchards in large numbers, either for food or in efforts to make egg burrows. These abandoned orchards undoubtedly have much to do with the large number of beetles present in this locality. Plate XI, figure 1, shows a view of one of these orchards which was cut back for the purpose of renovation. The result was that the trees developed a strong growth and were almost free from attack at the end of the season.

The reasons for the attack by beetles on apparently healthy trees, while important to know, can not yet be explained. Several orchards were observed where the beetles were attacking the trees in numbers without forming egg burrows. These orchards had borne crops continuously each year, but appeared to be becoming gradually weaker each season, and large quantities of sap oozed out and collected at the base of the trees during the summer months. In one case in which an orchard had been very badly injured, whitewashing the trees was tried, and the present season (1908) the trees appear healthy and thrifty with but few beetles present, these having worked into the smaller branches above the whitewash.

EXTENT AND CHARACTER OF INJURY.

When the beetles are present in large numbers their injury to the trees is quickly brought to the attention of the orchardist by the large amount of sap exuding from the trees through the many small borings made both in the trunk and limbs of the tree. (See Pl. X, fig. 1.) In some instances from 1 to 3 or more gallons of sap will flow from a single tree during a season. The writer observed one wild-cherry



WORK OF THE PEACH-TREE BARKBEETLE (PHLŒOTRIBUS LIMINARIS).

Fig. 1.—Orchard severely pruned April 19, 1908. Photograph taken July 7, 1908. Fig. 2.—Gum exuding through burrows made in bark of cherry tree. Fig. 3.—Removing stumps of trees supposed to have been killed by the barkbeetle. (Original.)

tree about 14 inches in diameter and from 75 to 80 feet high which had apparently been killed by the beetles, the bark having been completely eaten away from the tree.

The adults or beetles (see fig. 20, *a*, *b*) produce the primary injury to healthy trees, the work of the larvæ being secondary. The healthy trees, by repeated attacks of the adults, are reduced to a condition favorable to the formation of egg burrows. When the beetles are ready to hibernate in the fall they fly to the healthy trees and form their hibernation cells. These latter are injurious to the trees, for through each cell there will be a tiny flow of sap during the following season. (See Pl. XI, fig. 2.)

The greater the number of hibernation cells, the greater will be the amount of sap exuded; also, when the beetles come out of their winter quarters in the spring they bore into the bark of healthy trees from one-quarter to one-half of an inch, either for food or in an endeavor to form egg burrows. Later the beetles leave these burrows, either because the burrows become filled with sap or because the beetles seek the sickly trees for breeding purposes. Many more small channels are thus formed in the bark and from these sap oozes during the summer. Two means are therefore supplied by which the sap may flow from the trees—and this it does in many cases, forming large gummy masses around the trunks. Such losses for three or four years in succession necessarily reduce the trees to a very much weakened condition, and it then becomes possible for the beetles to form egg burrows and for the larvæ to finish the destruction of the tree. Plate XI, figure 3, shows the remains of an orchard presumably killed by *Phlœotribus liminaris*.

LIFE HISTORY.

HIBERNATION.

The insects spend the winter as adults in hibernation cells just beneath the outer layer of bark on both healthy and unhealthy trees. In the fall, from October to freezing weather, the adults of the fall generation are continually emerging and migrating to growing trees. They bore in through rough places on the bark and burrow along from one-quarter to five-eighths of an inch, forming hibernation cells, the openings to which are closed with the exudation from the burrow. In these cells they remain throughout the winter. The latest formed adults of the fall brood remain in the pupal cells until spring before cutting out, so that hibernation occurs both on dead and living trees, those on the live trees hibernating in regular hibernating cells and those on dead trees hibernating in the pupal cells.

With the first warm weather in spring—as early as the last of March in the latitude of Lakeside, Ohio—the beetles begin cutting their way out from their hibernation cells. They do not immediately leave these, but remain from four days to a week or more, most of them feeding for a while and then migrating to trees, wood piles, and brush heaps, or to anything upon which they can feed and in which make brood chambers.

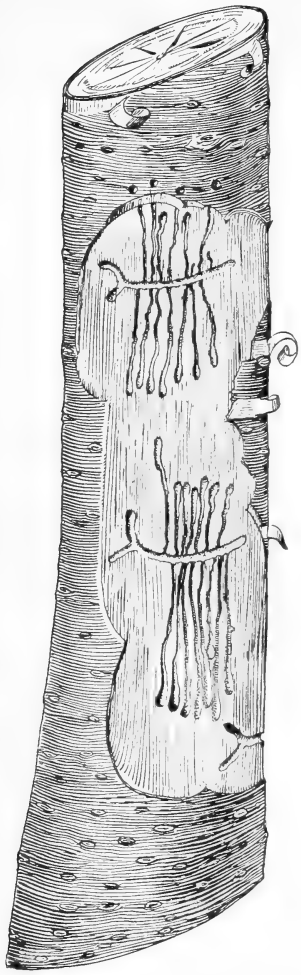


FIG. 18.—Work of the peach-tree barkbeetle (*Phlœotribus liminaris*): Galleries in limb of peach tree, November 20, 1908. (Original.)

THE ADULT.

HABITS.

The beetles fly but little during the morning hours, migrating from tree to tree for the most part between the hours of noon and night. During the day the beetles move about on the trees, the females seeking places in which to burrow and the males searching for burrows already started in which the usually accompanying male is lacking. After nightfall flight and movement over the tree cease.

The male beetles probably commence feeding as soon as they cut their way out of the pupal cell, and continue to feed more or less as long as they live. When in the brood chamber they excrete a brown bead-like frass, the food for this sex evidently being cut loose and passed back by the female. The female commences feeding as soon as she has cut into the edge of the bark, and feeds until she is too feeble to form egg cells.

The burrows of *Phlœotribus liminaris* can be very easily distinguished from those of *Scolytus rugulosus*, both from the outside and on the inside of the bark. The opening of the burrow of the former is very easily distinguished from the fact that the exudation from the burrow is held together by a fine, apparently silklike thread, which is secreted by both male and female. This holds the exudation over and partly in the mouth of the burrow. After going into the sapwood the female constructs a niche which later forms an arm

of the egg burrow. While an extension opposite this is being made the males copulate with the females at this point. At other times the males remain between the mouth of the burrow and this niche, occasionally going deeper into the burrow. Copulation ordinarily takes place at the fork in the burrow, and has been observed a number of times to last as long as fifteen minutes after the cutting away of the bark. The female rests with the posterior end of the abdomen just at the edge of the fork, the male operating from the adjoining niche. The sole function of the male seems to be that of attending the female, as none has ever been observed working.

The forks of the burrow may or may not be nearly equal in length, but usually they vary to quite an extent. They are, however, always more or less horizontal, running around the axis of the limb. (See figs. 18 and 19.) After being fertilized the female immediately sets about depositing eggs, and at this time the abdomen is very much swollen. During the construction of the burrow copulation occurs several times, so that the length of the burrow appears to depend upon the number of times of copulation. As soon as the egg is deposited the female covers it with frass, so that the main burrow is a circular tube of sawdust, outside of which occur the eggs. The method of egg deposition is as follows:

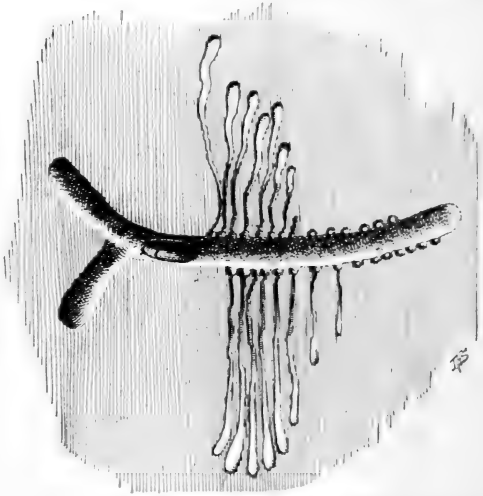


FIG. 19.—Work of the peach-tree barkbeetle (*Phlœotribus liminaris*): Galleries in wood of peach tree, May 18, 1908, Lakeside, Ohio. Enlarged. (Original.)

Having made the egg cell, the female backs out to the niche where, after turning around, she backs into the cell again, clinging to the side of the burrow. The egg is then placed in the cell, and after again turning around the female covers it with the sawdustlike frass. The egg cells are filled as soon as they are finished, and each is made as soon as the burrow has been extended far enough to make room for it.

From ten days to two weeks are necessary for the completion of the burrows. The males and females in the same burrow live until after most of the larvæ have developed into the next brood of beetles. The completed burrows of this species are more nearly equal in length

than those of *Scolytus rugulosus*, the maximum length being about $2\frac{5}{8}$ inches, with an average of $2\frac{1}{16}$ inches.

There are two complete broods each year—the summer brood and the fall brood, the latter being the hibernating one, the beetles appearing in early spring. Beetles of the summer brood appear in maximum numbers during the last half of August, as shown more in detail in the following table:

TABLE I.—*Emergence of summer brood of beetles of Phlœotribus liminaris.*

Date.[a]	Beetles reared in cages.	Beetles from insectary on window screens.	Date.[a]	Beetles reared in cages.	Beetles from insectary on window screens.
July 16	2	60	Aug. 25	40	.....
23	.....	30	26	60	1,500
24	.....	74	27	86	1,000
26	83	.....	28	69	600
27	.....	300	29	72	1,000
28	32	.....	Sept. 3	154	200
29	30	.....	4	111	.....
31	82	450	5	40	200
Aug. 4	68	.....	7	67	75
5	.....	350	10	18	.....
6	84	500	11	38	.....
9	151	.....	13	91	40
12	258	450	15	37	.....
15	.....	1,200	17	29	.....
16	.....	750	19	12	.....
17	.....	750	22	32	.....
18	317	1,750	24	21	.....
[b]21	327	2,500	29	7	.....
24	129	.....	Oct. 2	4	.....

[a] The first column shows beetles actually counted and taken from a breeding cage; the second row of figures shows, somewhat estimated, numbers of beetles gathered on screens at windows. All counts made between 4 and 6 p. m.

[b] This table shows August 21 to be the date of maximum emergence of beetles.

DESCRIPTION.

Average length, 2.25 mm., average width, 0.75 mm. Body elongate, subcylindrical, strongly punctured and with yellowish bristles arising from the punctures; color varying from light brown to almost black. Head globular, nearly vertical in front, anterior part fringed; eyes narrowly oblong, closely joined to the scape and extending about half their length below it; mandibles short and broad, distal part curved and strongly acute; mouth parts partly inclosed, gular suture distinct; funiculus of antennæ five-jointed; club compressed, composed of 3 triangular segments; first joint longer than wide, globular; scape circular, clavate. Thorax almost cylindrical, strongly angled at caudal end. First and second coxæ widely separated, globular; femur stout, outer edge serrated; tibia stout, compressed, lower half of outer edge serrated and ending in an apical tooth; tarsus stout, shorter than tibia, third joint bilobed, fourth indistinct, fifth as long as first and second together; tarsal claws simple. Ventral side of abdomen and posterior edge of last segment strongly concave; elytra anteriorly rounded and deeply margined, sides parallel, surface with regular striæ which contain circular, regularly placed depressions, elevated parts with yellowish bristles arising from faint punctures.

THE EGG.

The eggs of the first generation may be found about the third week in April, and, from that time on, the eggs of the first and second generation can not be separated, owing to the irregular emergence of beetles and the irregular forming of egg burrows. Eggs can be found in all stages of development up to the first week in October. The eggs of the second generation begin to appear about August 1.

Owing to the small series of eggs observed, the following data on length of the egg stage are not given as conclusive: Eggs of the first generation require from 17 to 20 days to hatch, while the eggs of the second generation hatch in about 8 to 10 days. The egg (fig. 20, *c*) is milky white when first deposited, being elliptical in shape, opaque, and measuring 0.06 mm. in length by 0.0385 mm. in diameter. The eggshell is fairly tough and the eggs may be very easily taken out of the egg cells. When working without interruption the female deposits from 2 to 10 eggs each day, in addition to making the cells.

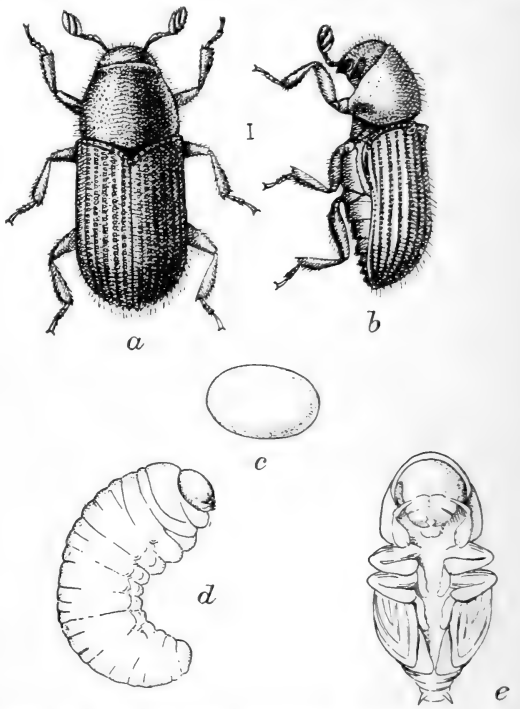


FIG. 20.—The peach-tree barkbeetle (*Phlœotribus liminaris*): *a*, *b*, Adult, dorsal and lateral views; *c*, egg; *d*, larva; *e*, pupa. Greatly enlarged. (Original.)

The number of eggs in egg burrows of this species varies, since the eggs are not always deposited at equal intervals. Each brood chamber may contain between 80 and 160 eggs. In the vicinity of Lakeside, Ohio, eggs can be found from April 20 until October 1. The egg burrow is not always made next to the sapwood, as in a tree where the bark is very thick the chambers are formed in the latter about one-fourth of an inch from its outer edge.

THE LARVA.

When the embryonic larva has become fully developed it lies in a curved position in the shell. After moving about a short time

it eats its way out at or just above the bottom of the egg and begins to feed along the under surface of the bark. When first hatched the larvæ are slightly longer than the egg but are less in diameter. After emerging from the eggshell they are found lying in a slightly curved position in the larval burrows. At first they are white but soon assume a pinkish tinge due to the bark in the digestive tube. The larvæ at first feed slowly and are several days getting away from the eggshell but progress faster as they grow larger. As they work out of the eggshell the sawdustlike excrement passed through the body fills these and holds them in place as the larvæ work out. The excrement voided by the larvæ marks their path, appearing like very fine sawdust.

The larvæ work away from the brood chambers at right angles, following, for the most part, the grain of the wood. For from one-half to three-fourths of an inch the larval burrows lie side by side, but later they diverge, so that the exit holes (Pl. X, fig. 2) form an irregular ellipse around the brood chamber. The larval burrows measure from $1\frac{1}{2}$ to $2\frac{7}{8}$ inches in length. When about to pupate in bark, which is about one-eighth of an inch or more in thickness, the larvæ work toward the outer edge of the bark and there form pupal cells. In these cells the larvæ continue to develop from one to three or more days before casting the skin and becoming pupæ.

Some 25 to 30 days are required for the full development of the larvæ. At the end of this time, having finished feeding, they void the excrement before pupating and have then a white appearance. Through the life of the larvæ the head is covered with a fine yellowish pubescence, which is more abundant about the mouth parts than elsewhere. (Full-grown larva, fig. 20, *d*.)

Description of full-grown larva.—Length, 2.15–2.75 mm.; width across thorax (widest part of insect), about 1.16 mm. Head subelliptical, about 0.6 mm. wide, yellowish, apex lighter; mandibles brownish, dark at tip. Body white, curved, tapering from thorax to rounded caudal end, quite wrinkled; legless, but on ventral surface of thoracic segments a small group of setæ at points of position of the adult's legs. Head with a few sparse setæ and a few on body. Body covered all over with many minute, short, stout spines.

THE PUPA.

The pupæ (fig. 20, *e*) are quite active, moving the abdomen continually back and forth. From 4 to 10 days are spent in the pupal stage, the pupa gradually assuming a dark color. When the pupal skin is cast, the beetles are very tender; they require from 4 to 6 days to completely harden and usually do not cut their way out from the pupal cells until they have fed a little, after which they remain in the pupal cells for from several days to two weeks longer.

Description of pupa about 3 days old.—Length, 2.5–2.66 mm.; width at widest part, 1.08–1.11 mm. Body uniformly white, except along sides of abdomen, which may show faint yellowish tinge. Eyes reddish brown; mouth parts (interior) faintly brownish. Abdomen ending in two lateral, whitish, minutely spinulose, brown-tipped horns.

PARASITES.

At the present date (December, 1908) no parasites of this species are known. Where *Scolytus rugulosus* and *Phlœotribus liminaris* bred in the same trees the usual parasites of *S. rugulosus* were found in great abundance, with a corresponding decrease in the number of adult *S. rugulosus*, while *P. liminaris* came out in numbers corresponding to the larval chambers. Efforts were made to rear the parasites upon limbs full of *P. liminaris*, but without success. Many minute mites—which, however, are not parasites—are found in and about the burrows and clinging to the hairs about the legs of the beetles and the ventral side of the thorax. They live on the excrement of the beetles and decayed matter in the burrows, simply using the adult beetles for the purpose of being carried from one place to another.

EXPERIMENTS WITH REMEDIES.

A list of the general experiments and a summary of the results is given below. Each experiment was made on a plat containing the number of trees mentioned.

No. 1.—Used 16 trees. One part by weight of lime: 2 parts by weight of cement; milk used to make a stiff whitewash and applied with a broom to 96 trees, 32 of which were used in experiment No. 2, with the addition of manure. Thirty-two more were used for experiment No. 3, with an application of commercial fertilizer. Sixteen trees of each plat were given a second application, forming experiments Nos. 4, 5, and 6.

Date of application, April 9, 1908.

No. 2.—Used 32 trees of experiment 1. Barnyard manure spread in a 7-foot circle about each tree, to get value of fertilizers.

Date of application, April 9, 1908.

No. 3.—Used 32 trees of experiment 1. Commercial fertilizer applied in a 7-foot circle about each tree.

Cement applied April 9, 1908; fertilizer applied May 7, 1908.

No. 4.—Used 16 trees of experiment 1, making a second application.

First application, April 9, 1908; second application, July 3, 1908.

No. 5.—Used 16 trees of experiment 2, making a second application.

First application, April 9, 1908; second application, July 7, 1908.

No. 6.—Used 16 trees of experiment 3, making a second application.

First application, cement, April 9, 1908; fertilizer, May 7, 1908. Second application, July 3, 1908.

No. 7.—Used 2 pounds fish-oil soap per gallon of water (dissolving soap in boiling water) for first application. Used 1 pound of soap to 6 gallons of water for second treatment. Twenty-four trees treated, 16 to be used for experiments 8 and 9.

First application, April 10, 1908; second application, July 7, 1908.

No. 8.—To each of 8 of the 24 trees treated in experiment 7 added barnyard manure to find value of fertilizers.

First application, April 10, 1908; second application, July 7, 1908.

No. 9.—To remaining 8 trees of experiment 7 added commercial fertilizer, 4 pounds to each tree, spreading in a 7-foot circle.

Fertilizer added May 7, 1908; second application, July 7, 1908.

No. 10.—One gallon carbolineum mixed with 20 pounds of flour, then 25 gallons water added to make emulsion; sprayed 72 trees, 48 of which were used for experiments 11 and 12 to get value of fertilizers.

Sprayed whole tree April 10, 1908; sprayed trunks and limbs below foliage July 6, 1908.

No. 11.—Used 24 trees of experiment 10, and added barnyard manure, spreading it about tree in 7-foot circle.

First application, April 10, 1908; second application, July 7, 1908.

No. 12.—Used 24 trees of experiment 10, and added 4 pounds of commercial fertilizer to each tree, spreading it in 7-foot circle about tree and harrowing in.

First application, April 10, 1908; second application (3 pounds commercial fertilizer), July 6, 1908.

No. 13.—Used 1 gallon carbolineum, emulsifying it with 4 pounds soap (dissolved in 4 gallons of water), and diluting the whole to 8 gallons; sprayed 144 trees, 96 of these to be used in four more experiments.

Application made April 10, 1908.

No. 14.—Used 48 trees of plat 13. Sprayed twice.

First application, April 10, 1908; second application, July 6, 1908.

No. 15.—This was to have been a third spraying, but was found unnecessary on account of absence of beetles.

No. 16.—Used 24 trees of experiment 13. Barnyard manure (to get value of fertilizers) spread about trees in a 7-foot circle.

First application, April 10, 1908; second application, July 6, 1908.

No. 17.—Used 24 trees of experiment 13. Commercial fertilizer added, 4 pounds to each tree, spread in a 7-foot circle to get value of fertilizer.

First application, April 9, 1908; second application, July 3, 1908 (3 pounds fertilizer).

No. 18.—Sprayed 6 trees with pure carbolineum without seeming injury to the trees.

Application made April 9, 1908.

No. 19.—Used 25 pounds of lime, 15 pounds sulphur, 6 pounds resin, 3 pounds arsenate of lead, and 50 gallons of water. Applied the mixture with a brush to trunks and large limbs of 6 trees.

Application made April 17, 1908.

No. 20.—Same as experiment 19, plus barnyard manure. Two of 6 trees in experiment 19 used.

Application made April 17, 1908.

No. 21.—Same as experiment 19, plus commercial fertilizer. Two of 6 trees in experiment 19 used.

Application made April 17, 1908.

No. 22.—One gallon carbolineum, 1 gallon lard, and 25 pounds resin. Painted trunks and larger limbs of 5 trees.

Application made April 17, 1908.

No. 23.—One bushel tobacco stems boiled for one hour in 4 gallons of water; one-half bushel stone lime and 4 quarts salt added; one-half pint crude carbolic acid used in each 12 quarts of the liquid. All gum and rough bark scraped from the trees and the paint put on with a broom.

Applied the mixture to 72 trees April 22, 1908.

No. 24.—Used 24 trees of experiment 23. Same treatment, plus barnyard manure spread in 7-foot circle about each tree.

Application made April 22, 1908.

No. 25.—Used 24 trees of experiment 23, plus commercial fertilizer spread in 7-foot circle about each tree.

Applied April 22, 1908; fertilizer applied May 7, 1908.

No. 26.—One gallon chloronaptholeum, emulsified with 4 pounds of soap (dissolved in 4 gallons of water); then added water enough to dilute to 25 gallons. Sprayed 120 trees.

First application, April 22, 1908; second application, July 7, 1908.

No. 27.—Used 24 trees of experiment 26; added barnyard manure, spreading it in a 7-foot circle about each tree.

First application, April 22, 1908; second application, July 7, 1908.

No. 28.—Used 24 trees of experiment 26, adding commercial fertilizer, 4 pounds to each tree, spreading it in a 7-foot circle.

First application, April 22, 1908; fertilizer added May 7, 1908; second application, July 7, 1908 (3 pounds fertilizer added).

No. 29.—One gallon chloronaptholeum mixed with 22 pounds flour to emulsify, added to 30 gallons water, and put on 120 trees with spray pump.

First application, April 17, 1908; second application, July 13, 1908.

No. 30.—Used 24 trees of experiment 29; added barnyard manure to get value of fertilizer.

First application, April 17, 1908; second application, July 13, 1908.

No. 31.—Used 24 trees of experiment 29, adding commercial fertilizer, 4 pounds, to each tree.

First application, April 17, 1908; fertilizer added May 7, 1908; second application, July 13, 1908.

No. 32.—Six pounds arsenate of lead to 50 gallons water; 3 pounds lime added to neutralize the free arsenic. Put on heavy spray; pruned trees before spraying; 170 trees sprayed.

First application, April 20, 1908; second application, July 13, 1908.

No. 33.—Boiled lime and sulphur spray (15 pounds lime, 15 pounds sulphur, 50 gallons water). Excessive application made to 200 trees.

First application, April 24, 1908; second application, July 13, 1908.

No. 34.—Self-boiled lime-sulphur wash (15 pounds lime, 10 pounds sulphur, 50 gallons water). Water added slowly so as to prevent burning, stirring vigorously during the process. Sprayed 300 trees.

First application, May 18, 1908; second application, July 13, 1908, to trunks and larger limbs.

No. 35.—A stock solution of kerosene emulsion, 20 per cent strength, was made and to each gallon of stock solution 2½ gallons rain water were added. Applied with spray pump.

Application made April 20, 1908.

No. 36.—Fumigated 6 trees with hydrocyanic-acid gas for one hour, first scraping off all gum and rough bark. Treatment given August 24, 1908.

No. 37.—Tree tanglefoot. Put bands around 12 trees and then covered bands with tanglefoot. Application made April 25, 1908.

No. 38.—Renovation block. Pruned back severely about 100 trees (girdling 4 trees for traps and not treating them further); applied fertilizer twice and kept trees cultivated all summer.

First application, April 19, 1908; fertilizer added May 7, 1908 (4 pounds per tree). Second application, July 3, 1908 (3 pounds fertilizer added).

No. 39.—A duplicate of experiment 17 tried on 200 trees; pure whitewash was applied as a second treatment.

Emulsion applied April 21, 1908; whitewash applied September 1, 1908.

No. 40.—Placed pieces of branches as traps in trees of small orchard to see if beetles would settle on them.

No. 41.—One-half barrel kerosene emulsion used instead of water to make a good stiff whitewash, applying with broom to plat of 200 or 300 trees.

First application made May 4, 1908; second application, July 9, 1908.

No. 42.—One gallon of chloronaptholeum added to every barrel of whitewash used. Whitewash made as thick as possible and applied with a broom to plat of about 200 trees.

First application, May 6, 1908; second application, July 9, 1908.

No. 43.—One gallon of Avenarius carbolineum added to each barrel of whitewash used; whitewash made as thick as possible and applied with a broom to a plat of about 200 trees.

All fertilizer used in above experiments was of the following formula:

	Per cent.
Phosphoric acid	8
Nitrogen	5
Potash	2

All trees fertilized made a growth of rich green foliage and the trees looked healthy, yet many of them were again attacked by the beetles.

RESULTS OF EXPERIMENTS.

The first 6 experiments seem to show that whitewash acts as a repellent, not affecting the beetles once they are in the bark, but if the trees are kept well coated the beetles do not seem to attack the whitewashed parts. The addition of fertilizer to the trees causes a strong flow of sap which, exuding through the burrows, seems to repel the beetles. The treatments given in Nos. 7, 8, and 9 seemed to have no effect whatever. In experiments 10, 11, and 12 the beetles in the tree at the time of application appeared to be killed, but the mixture did not act as a repellent and beetles settled on the trees again in a short while. Experiments 13, 14, 15, 16, and 17 were more promising, and two applications a season would undoubtedly keep the beetles down. The expense of these experiments, however, makes them impracticable as tried here. In experiment No. 18 all beetles attacking the trees at the time of application were killed, and others did not settle on the trees during the entire season.

The cost of the materials used in this experiment, however, makes the treatment impracticable. Experiments 19, 20, and 21 had no effect whatever, neither killing the beetles in the trees nor repelling others. In experiment 22 all trees treated were killed. Experiments 23, 24, and 25 gave very good results, the whitewash sticking well and the beetles not attacking the trees until long after the whitewash had fallen off. Experiments 26, 27, and 28 seemed to have had very little effect on the beetles in the bark and did not repel later attacks. Ex-

periments 29, 30, and 31 failed to give any beneficial results, the emulsion being very poor, as the oil became partly separated from the mixture before the latter could be applied. Experiments 32, 33, 34, 35, 36, and 37 gave only negative results, neither killing the beetles in the burrows nor repelling later attacks. In experiment 38 a plat of 100 trees was used. Fifty of the trees were very severely cut back and 4 or 5 of them, being too weak to recover, died. The other 50 trees were sprayed with lime-sulphur wash. At the end of the season the pruned trees had produced a strong, healthy foliage and the beetles were attacking them but little. The untrimmed trees were badly attacked and had thrown out a scant, sickly-looking foliage. Experiment 39 gave satisfactory results. All of the beetles in the trees at the time of application were killed and no more settled on them until about the last of September; then, a few having settled, the trees were whitewashed and further injury was stopped. The cost of this treatment, as made here, prevents it being practicable for a large orchard unless the amount of material used can be reduced with equally good results for the weaker emulsion. Experiment 40 showed that the beetles attack the trees in which these cut branches were placed without settling on the cut branches. Experiments 41, 42, and 43 showed the most practicable, and at this time the most likely remedies. These are the combinations of a whitewash and an oil, the whitewash probably being the main factor in repelling the beetles. The cost of these experiments was $1\frac{1}{4}$ cents per tree for each application. The trees in these plats, while not entirely free from further attack during the season, suffered considerably less than surrounding plats of trees.

METHODS OF CONTROL.

Pending further investigation, the following treatments are suggested as being practicable and to a certain degree favorable:

For trees seriously injured.—Severely trim back the trees and apply barnyard manure or commercial fertilizers; then apply a thick coat of whitewash three times a season, the first application to be made the last week in March, the second application during the second week in July, and the third application about the 1st of October.

For trees apparently healthy but slightly attacked.—Paint the trees with a thick coat of whitewash three times each season as in the previous treatment, applying it to the trunks and larger limbs. The whitewash applied at the times specified will act as a repellent, the emergence of the beetles being slightly later than the dates given for the different applications. Add one-fourth pound table salt to each pail of whitewash, thus making the latter more adhesive. All of the dead or nearly dead limbs and trees should be removed and burned as fast as they appear in an orchard, as this will destroy the breeding places.

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