THE CANKER-WORM

An Orchard and Shade Tree Pest.

by

Walter H. Wellhouse

Submitted to the Department of Entomology and the faculty of the Graduate School of the University of Kansas in partial fulfillment of the requirements for the degree of Master of Arts.

Approved: S. J. Hunter
Department of Entomology.

May 15, 1917.

TABLE OF CONTENTS

INTRODUCTION

This paper is the result of two year's observations on the Spring Canker-Worm in Lawrence and in other portions of the southern division of Kansas where the writer has been called in performing the duties of Assistant State Entomologist, and of two month's searching through the available literature concerning the canker-worms. During the present season the writer, under the direction of Professor S. J. Hunter, State Entomologist, has been in charge of a municipal campaign to control the Spring Canker-worm on the elms of Lawrence.

In preparing the paper I have been greatly aided by kindly suggestions from Professor Hunter, by free access to the notes of Mr. B. P. Young, of the Kansas University Insectary, and by Mr. R. H. Beamer, Assistant Curator of the Kansas University Entomological Museum, who made most of the photographs for me. To Mr. C. D. Bunker, Curator of Mammals, in the Dyche Museum, I am indebted for the use of his unpublished notes on birds which eat the canker-worms. Mention should also be made of the efficient stenographic work furnished by Miss Kathryn Bonar in copying this paper.

HISTORICAL NOTES.

The term "canker-worm" is much older than our knowledge of the two species of Geometrids now called canker-worms. The name is said to have originated in England about 1530. In Shakespeare's "Two Gentlemen of Verona" published at the end of that century we find this line: "In the sweetest bud The eating canker dwells."* Again, in the first authorized English version of the Bible, published in 1611, we find the passage: "That which the locust hath left hath the cankerworm eaten." #

The name seems to have been applied to any leaf eating larvae by the people of England, regardless of species. It is now generally restricted to the two species designated by Dr. Riley in 1873 as the Spring Canker-worm and the Fall Canker-worm. Paleacrita vernata Peck, called the Spring Canker-worm, and Alsophila pometaria Harris, called the Fall Canker-worm, are in all probability native to North America and are found only on this continent. Alsophila aescularia, an European species, is, however, very closely related to our Fall Canker-worm and resembles it so closely in

*Act I, Scene I. #Joel I, 4.

the adult state that an inexperienced observer might easily mistake the one for the other.

In America our first reference to the canker-worm seems to be that of John Hull in 1661, He states that "the canker-worm hath for four years devoured most of the apples in Boston, that the apple trees look in June as if it was the ninth month". Samuel Deane writing in 1790 at Worcester, Massachusetts, informs us that the canker-worms were pests in the cultivated parts of New England at least as early as 1740.

In 1793 the Massachusetts Society for Promoting Agriculture offered a large premium for a satisfactory natural history of the canker-worm, and another premium for a method of destroying the canker-worm. The latter premium was offered from year to year for twenty years until, still unawarded, it was abandoned. The former premium was awarded to Professor William Dandridge Peck, of Kittery, Maine, for his essay on the canker-worm. This essay published in 1795 is the first scientific account of the insect which we have, and in fact marks the beginning of scientific entomology in America.

Extracts from the Original Essay on the Canker-worm, by William Dandridge Peck, published in 1795.*

*Riley's Seventh Mo. Report pp. 89-90.

"To cultivate a knowledge of insects, merely for their splendid plumage or gorgeous colors, is, indeed, contemptible employment; but to inquire into the purposes of their being and the part they are destined to perform in the economy of Nature, is to study the wisdom of that Omniscient Being whose mandates they execute with the greatest exactness.

'These insects (the Canker-worms) appear in the Spring earlier than any other of the moth tribe--about the middle of March. Their rise, however, from the earth will be delayed or hastened according to the temperature of the atmosphere and state of the soil. They are found under a double form, the males being furnished with, and the females being destitute of, wings. This circumstance necessitates the females to ascend the tree by its trunk in order to deposit their eggs upon the branches. The males by their wings resort to them and are found in the evenings hovering round the trees. In three or four days after they begin to rise, they are found sub-copula. This office is performed in eleven or twelve days after their first appearance. The males die and disappear. In thirteen days the females deposit their eggs. These they place in the crannies of the bark in the forks of small branches; and where there are spots of moss upon the smaller limbs they seem most fond of insinuating themselves into the cavi-

ties between its leaves. For this purpose the females are furnished with a tube through which the egg is passed, with which she investigates the apertures in the bark or moss, and ascertains their depth. Each female lays at a medium an hundred eggs. The ultimate purpose of their being thus performed, they die.

'The egg is elliptic, 1-30 of an inch in length, of a pearl color, with a yellowish cast. As the included animal advances in ripeness the egg assumes a brownish hue; in twenty days is of a lead color, and with a moderate magnifier the larva may be seen to move in the shell. On the twenty-first day the larva breaks from its prison, is one line in length, and furnished with ten feet--six anterior and four posterior. They are commonly hatched about the time that the red currant is in blossom, and the apple tree puts forth its tender leaves.

'On the twenty-sixth day from their quitting the egg they cease from feeding and descend by the trunk of the tree; when arrived at its foot they, with great labor, penetrate the earth near it to different depths; and this appears to depend in part on the quality of the soil and in part on the vigor of the animal. In grass land they are found from one to four inches beneath the surface, and when the trees stand in plowed land, if the soil be loose, they penetrate to the depth of seven or eight.

'It has been observed above that they descend by the trunk of the tree; all which descend in this manner enter the earth near it. This is their natural and regular course, and hence the greatest number of them is found within a circle, whose radius extends four feet from the trunk. But some will always be found at a greater distance, according to the area which the tree covers; for if dislodged by wind or accident at the time when they are about to seek the earth, they cover themselves near the spot they fall on.

'The chrysalis state comes on in twenty-four hours after the larva has penetrated the earth; and it appears that the insect is soon perfect, since a course of warm weather has been found to raise some of them from the earth in the month of November. While they are in chrysalis they are uninjured by frost. Their natural and regular time of rising is about the middle of March, but happens sometimes as early as the twelth, and is sometimes retarded to the twenty-fourth, according to the warmth or coldness of the season. They continue to rise for a longer or shorter time, according to the greater or less depth at which they lie; and the extrication of the frost from the earth--commonly from twenty to thirty days. Like others of the moth kind, they are active only in the night, and in the day time sit close to the bark of the tree, whose color is so similar to theirs that they are not seen without near inspection.

'The principal check provided by Nature, upon the too great increase of this insect is the Ampelis garrulus of Linnaeus, called by Mr. Catesby, the Chatterer of Carolina, and in the Reverend Doctor Belknap's History of New Hampshire, Cherry-bird. This bird destroys great numbers of them while in the larva state. Another check is a disease which may be called Deliquium, and is probably occasioned by a fermentation of their food. In this disease the whole internal structure is dissolved into a liquid, and nothing is entire but the exterior cuticle, which breaks on being touched."

Since Peck's time scores of entomological writers have published accounts of the canker-worms. Among the most complete accounts are the one by Harris, in his Treatise on Some of the Insects Injurious to Vegetation, 1852, in which he suggests the existence of two species of canker-worms, and calls those moths which arise in the Fall pometaria; and that of Riley in the Third Report of the United States Entomological Commission, 1882.

DESCRIPTION.

The canker-worms belong to the family Geometridae (meaning earth measurers) the larvae of which are called measuring-worms or loopers. They are distinguished from other caterpillars by having a less number of fleshy supporting legs under the hind portion of the body. The normal number of such so-called prolegs in caterpillars is ten, while the Geometrid larvae have but four or six. This lack of the foremost prolegs causes them to loop up the middle of their bodies in moving from place to place.

There are two distinct species of canker-worms found in the United States. Peck, Harris, Packard and other writers before 1874 had confused these species, but, in that year, Dr. C. V. Riley gave a complete description of both species, showing them to be clearly separate. His descriptions of the two species as given in the Third Report of the United States Entomological Commission are as follows:

The Spring Canker-Worm.

(*Paleacrita vernata*, Peck)

Imago.- The Spring Canker Worm is distinguished in the perfect state by the first seven joints of the abdomen bearing each two transverse rows of stiff reddish

spines, pointing posteriorly, more prominent in the female than in the male, and often giving the abdomen a reddish appearance. It is rather smaller in aize than the Fall species, the male measuring from tip to tip of wings when expanded from about five-sixths of an inch (21mm.) to over an inch and a quarter (32 mm.), and the female from a fifth to a little over a third of an inch (5-9 mm.) in length.

Male.- The wings of the male are silky and delicate, the front ones marked with three transverse jagged, dark lines, sometimes wanting, except on the front edge of the wing, where they are always more distinct, dividing this portion of the wing into four very nearly equal parts; they have also a somewhat jagged, pale, submarginal line. The upper surface is brownish-gray in color, while the hind wings are pale ash or very light gray, with rarely any dots or markings. Some specimens have no dots whatever, even when fresh from the chrysalis; and captured specimens, owing to the looseness of the scales, always have the marks more or less effaced.

Indeed, the ornamentation of the wings is extremely variable. In many specimens the middle portion of the front wings, within the three dusky lines, is quite pale and mottled with grayish-green, while the basal and terminal portions are marked with brown, thus making the contrast greater.

Female.- The body, legs, and antennae of the female are clothed with whitish and brown or black hairs, and along the middle of the back of the abdomen there is a black stripe, of which, sometimes, however, all but the ends is more or less obsolete. The color of the female is rabbit-gray, or speckled black and white. The abdomen is acutely tapering and ends in a two-jointed ovipositor.

Egg.- The eggs somewhat resemble in form hens' eggs, but are more elongated, They are very delicate in texture, yellowish, reflecting prismatic colors, and are smooth, though often appearing roughened by transverse and longitudinal irregular depressions. The eggs are laid in irregular masses in secreted places.

Larva.- The larva has but four prolegs, in addition to the usual three pairs of thoracic legs on the anterios portion of the body, these prolegs being situated on the 9th and the last joints of the body. (It may thus be distinguished from the larva of the Fall species, which has an additional short pair of prolegs on the 8th joint.

The young larva is dark olive-green, or brown, with a black, shiny head. The full grown worm varies greatly in the intensity of its markings, ash-gray, green and yellow ones occurring in the same brood. The most constant character by which it may

be distinguished from other span-worms of the same size, is the pattern of the head, which, no matter what the general hue of the body may be, is distinctly mottled and spotted, the top pale, and two pale transverse lines in front.

Another distinguishing character is the occurrence of two pale, narrow lines on the middle of the back, the space between them usually being dark and occupied, on the anterior edge and on the middle of joints 5, 6, 7 and 11, by black marks somewhat in the form of X; these marks being represented by dots on the other joints. There are two rather prominent tubercles on top of the eleventh joint, preceded by two white spots.

The full grown larvae measure from seven to nine-tenths of an inch (18-23 mm.) in length.

Chrysalis.- Pale grayish-brown, with a dark green tinge on the wing-sheaths. Remarkable for its robustness and for the large size and prominence of the palpi. A single bifurcate thorn at extremity. Length 0.35 inch (9 mm.); diameter across thorax 0.12 inch (3 mm.). Both sexes in the chrysalis state have wing-sheaths, those of the female being thinner than those of the male, and shorter, extending only to the posterior edge of the fourth joint of the abdomen, while in the male the wing-sheaths are one joint longer. The chrysalis of the male is more slender

than that of the female.

The cocoons are simple earthen cells, slightly lined with silken threads, which are easily broken to pieces.

The Fall Canker-Worm
(*Alsophila pometaria* Harr.)

Imago.- Under critical examination the Fall Canker-Worm is readily distinguished from the Spring species. On the average the imago is somewhat larger and more glossy; the fore wings are a little more elongated toward the apex, making the outer edge a little longer and more oblique; they are of a peculiar ochreous-brown tint, as in the European *aescularia*; they have a distinct white spot on the front edge, and are crossed by two pale, jagged bands, along the sides of which are several blackish dots.

The hind wings have a more or less distinct pale, curved line across their middle. The female is uniformly dark ash-gray above, paler beneath, and with naked antennae; her legs and abdomen are smooth and glistening, and she has no extensile ovipositor.

Thus these imagos lack the characteristic dorsal spines of *vernata*, the dusky marks across the front wings of the male, and the pubescence of the female.

Egg.- Length, 0.25 inch; average diameter two-thirds the length; flattened at top where it is somewhat larger than at base. Color of crown purplish-gray, the surface slightly corrugated, with a central dimple and a brown circle just within the border; sides smooth and more silvery, and generally somewhat compressed by pressure of adjacent eggs. Laid in exposed situations, in patches or strips, attached in regular rows, and fastened to the bark in a slightly slanting position so that one edge of the crown is a little above, the other a little below the general level.

Larva.- Color pale-brownish, marked with dark brown and yellow as follows: The dorsum uniformly dark brown; the sides with three pale narrow lines, more or less irregular and mottled, but always well relieved, the two superior ones white, the lowermost yellowish; the subdorsal space between the upper two of these lines, pale; the stigmatal between the lower two darker, especially in middle of the joint around stigmata; the thoracic joints dark with the pale lines somewhat narrower and running up to the head. On joint 11 these lines are constricted or entirely broken, so as to leave a dark band across the middle of the joint. The head is dark brown above and at sides, but paler in front. Cervical shield also dark with the yellow lines running though it. Venter olivaceous, the legs more reddish, there being three pairs of prolegs, the pair

on joint 8 only half as long as those on 9, but with perfect hooklets; the thoracic legs quite hirsute and terminating generally in two thorns. Piliferous spots obsolete and with a very few scarcely distinguishable pale hairs, except on anal shield and legs, where they are stouter. Anal shield and legs with brown piliferous dots. The larva when first hatched is yellowish-white, with the black eyelets showing distinctly on the pale head. It soon deepens to pale olive green, with a large pale-yellowish head and pale legs. The light lines of the mature larva are, at this early stage, faintly indicated and the piliferous spots give forth short, fleshy, pale hairs. The third pair of prolegs is distinctly visible, but is not used in locomotion. After the first molt the head and thoracic legs become somewhat browner, and the olivaceous green more bluish, After the second molt, the dark colors show much more distinctly.

It varies somewhat in intensity of color, and in some the light and dark browns are not so sharply separated, but the dorsum is generally uniform and the three lateral yellow lines distinct. Up to the second or last molt, the general color is, with rare exceptions, greenish; but in the last stage, the dark-brown or black predominates, and is sometimes so general that there is but the faintest trace of the superior yellow lines. Occasional specimens, even when young, show

in the subdorsal dark space one, and in the dorsal dark space two, very fine and faint pale lines. Differs entirely from vernata in lacking most of the characteristic spots in front of the head of that species, and the two pale transverse marks; in having the dorsum darker instead of lighter than the rest of the body; in lacking the medio-dorsal pale lines and the characteristic X-like marks; in the broader more conspicuous pale lateral lines, and in the subdorsal space being darker than the stigmatal; and lastly in the additional, though atrophied, abdominal prolegs. It is a smoother larva.

Chrysalis.- Color light brown, with the wing-sheaths, a medio-dorsal shade, sutures and stigmata darker. Length 0.30-0.35 inch; stout, with the wing-sheaths and their veins distinct in the female; a dorsal, bifid, decurved tubercle near the tip of anal joint.

Cocoon perfect of fine, densely spun silk of a buff color, interwoven on the outside with particles of earth; never breaking open except by force or purpose.

Some Similar Measuring-Worms.

Several other species of Geometers or measuring-worms having somewhat similar habits are likely to be found with the canker-worms but rarely are so numerous or so injurious as the latter. The lime-tree span-worm Erannis tiliaria Harris is found on apple, elm, linden and various forest trees. The moths appear in the Fall at the time the adults of the Fall Canker-worm are seen, and the wingless females crawl up the trees to lay from one to five eggs in a place tucked away from view beneath the scaly bark. The larvae work at the same time the canker-worm larvae are eating but they may be readily distinguished by their yellow and black stripes and larger size; the span-worms being about one-third longer than the canker-worms.

The mottled umber-moth (Erannis defoliaria Clerck), a common and destructive orchard pest in Europe, has become established in British Columbia. The larva feeds on various fruit and shade trees and is very similar to the lime-tree span-worm, the main difference in appearance being that the larva of the umber-moth has stripes of reddish-brown in place of the yellow ones on the back and the spiracles are in the center of reddish-brown blotches. The life history is identical with that of the lime-tree span-worm.

Another moth similar to the Fall Canker-Worm is Bruce's measuring-worm (Rachela bruceata Hulst). It seems to be a northern species injurious to apple, maple, and poplar trees in Canada and in some of our northern states. According to Slingerland and Crosby, the wingless female moths are about one-third inch long, light brownish-gray, and closely resemble the female Fall Canker-worm, differing in being only about two-thirds as large and in having slightly longer stubs of wings. The winged male moths have a wing expanse of about 1 1/8 inches and are of a general pale brownish color, the wing veins being quite distinctly outlined by darker scales. The eggs are usually laid singly where readily seen in the crevices of the bark. The life history is similar to that of the Fall Canker-worm. The full grown larva is about 3/4 inch long and its general color is apple green, with three narrow yellowish-white stripes along each side of the body. Like the Spring Canker-worm it has two pairs of prolegs. The head, thoracic and anal shields, and a spot on the anal prolegs are sometimes blackish, but occasionally light colored like the body.

Working with the canker-worms in the states bordering the Great Lakes another measuring-worm is occasionally found, Phigalia titea Cramer. It is designated the half-winged Geometer by Slingerland

and Crosby "because of the nearly half developed condition of the wings of the female moth". The larva feeds on apple, several forest trees, blackberry and rose. When full grown it is 1 1/2 inches long, "of a general olivaceous-brown color with a rough black-mottled head. Eight pairs of narrow, irregular, black stripes extend along the body, the four pairs on the underside being less distinct and ending at the first of the two pairs of pro-legs. The hair-bearing spots are elevated into shining black papillae, those in the hind row on the first four abdominal segments being considerably larger".

None of these measuring-worms have as yet been reported as injurious in Kansas or adjacent states, but like the canker-worms they may suddenly appear in destructive numbers where they have not been known to occur.

Geographical Distribution.

Both species of canker-worms seem to have been first known to us in New England although there is some difference of opinion as to their original home. Peck states that "the Canker-worm is said to have been observed first in the southern states, where it is probably a native". Riley disagrees with this statement and says "no authority is given for the assertion that the insects came from the south, and as they seem never to have occurred in the region which Peck intended by that word--i.e. the southern Atlantic States--the assertion must be discredited".

Coquillett, writing in 1895, says the Spring Canker-Worm "ranges from Maine to Iowa, and southward to Texas, but is more restricted along the Atlantic seaboard, where it has not as yet been reported as occurring south of New Jersey. The Fall Canker-worm is more essentially a northern insect, occurring from Rhode Island to Canada, and westward to Lake Superior; and quite recently it has been found in large numbers in some of the orchards of northern California." Quaintance stated in 1907 that "for several years the Spring Canker-worm has been quite troublesome in a few old orchards in northern Virginia". Sanderson in 1912 adds Colorado to the list of states where both Spring and Fall species are present. Slingerland and

Crosby in 1914 write that "the Spring Canker-worm is common in Canada and in the northern United States from Maine westward to Kansas, thence southward through the Mississippi Valley to Texas. It also occurs in California, (The Fall Canker-worm) is now common in Canada and throughout the northeastern United States, extending westward into Ohio; and in 1891, orchards of apple, prune, plum, apricot and cherry were ravaged in western California, apparently by this eastern Fall Canker-worm. It is often destructive in apple orchards, sometimes working with the Spring Canker-worm or on neighboring orchard or shade trees; the two species have worked separately for several years on elm trees about a mile apart near Ithaca, N. Y.". Essig in 1915 states that both species occur in Northern and Central California. Wilson and Lovett in 1913 call another Geometer, Notolopus sp. which was found in Oregon, the canker-worm, but do not record either of the two species here treated as being present in that state.

The canker-worms are spread to new localities principally in the larval stage; the larvae dropping onto trains, automobiles or other vehicles and after being carried some distance then dropping off and seeking food in the new locality. They are sometimes transported in the egg stage on nursery stock from infested regions also. Locally, the larvae are spread from tree to tree by the wind carrying them while suspended on their silken threads, and they are also carried on the clothing of persons passing beneath the infested trees.

History and Distribution in Kansas.

In Kansas the Fall Canker-worm has not yet been recorded. The Spring Canker-worm seems to have been present sometime before 1873 although it did not become noticeably injurious until 1879.

Mr. G. C. Brackett, reporting for the Standing Committee on Entomology before the State Horticultural Society, in 1873, says "there is not any reason, judging from the past, to believe that the canker-worms will ever become so numerous in this climate as to do us any material injury. I have not seen it here only in a very few instances, and am of the opinion that in these few cases the eggs had been introduced upon trees brought from the more northern and eastern states. They continued one season, and, from some debilitating cause, weakened and died out".

Colonel D. W. Houston, of Garnett, Anderson County, gave some notes on the insects at a meeting of the State Horticultural Society in 1880, which show the fallacy of Mr. Brackett's prediction.

Colonel Houston said:

"The first I noticed of the Canker-worms in my orchard was about the 20th of April, 1879. I had not been among the trees for several days and was surprised one morning to see the leaves turning brown. This orchard consists of 4,000 trees on upland prairie.

I enclosed specimens of these worms to the Secretary of the State Horticultural Society and received the answer that the specimens sent are the much dreaded New England Canker-worms.

In ten days from the time I first saw them there was not one to be seen. They had all dropped down and gone into the ground. They had defoliated about 300 trees.

The first weeks of January 1880 were quite mild. I find the following entry in my diary:

'Jan. 21: I find many little moths some with wings but mostly wingless at the roots of my apple trees and under the rough bark on the bodies of the trees, I suppose they are the canker-worm moth. They are about 3/8 inches long of a dirty grey color.

'The pest is spreading. Last year it was in three other orchards that I know of and I very much fear will overrun the country if not checked."

By 1882 we hear of it in Neosho, Allen, Woodson, Montgomery, Chatauqua: and then in the southern portion of Douglas County, where "it appeared in the fine and extensive orchards of Mr. A. C. Jacot, residing near Prairie City, in large numbers." From the report of the State Horticultural Society for 1884, I have taken the following paragraph of a letter by Judge Fred Wellhouse, who had an extensive orchard in Leavenworth County:

"We have been troubled with this worm for a number of years on 35 or 40 acres of our orchard; and last year they stripped every leaf from about 15 acres, then the fruit and finally commenced on the bark. After their disappearance the trees again leaved out, but made a stunted feeble growth, and I am sure they would have finished them this spring if we had not interfered, as they hatched out by the million again, and every leaf seemed to be covered with them."

In 1885 canker-worm damage was reported from Wilson, Elk, Cowley, Atchison, Republic, Ottawa, Riley and Ellsworth counties, showing that practically all of the eastern half of Kansas had by this time become infested.

From 1886 to 1896 the canker-worm did very little damage. In 1896 it was reported to be defoliating apple trees in a few orchards in Butler County. In 1897 and 1898 the injury was again widespread over the state. In March 1898 a bulletin was issued by E. E. Faville and P. J. Parrott of the Kansas Agricultural Experiment Station, giving the life history and control measures for the Spring Canker-Worm.

After 1899 reports of extensive canker-worm injury again disappear until 1911, although a few localities reported slight injury in 1906, 1907, 1908 and 1909. In 1911 the apple trees in southern counties were in many cases completely defoliated. In 1912 and 1913 the injury was increasing and all parts of the state report damage in 1914 and 1915.

From these notes which have been obtained mostly from the reports of the Kansas State Horticultural Society and of the Kansas Agricultural Experiment Station, it seems that we have had three main canker-worm outbreaks in the state; the first one from 1880 to 1885, the second from 1896 to 1899, and the third from 1913 to the present year.

Although Professor Faville mentions the elm and other shade trees as being attacked by the canker-worm in 1898 very little notice was given to the injury of elm trees by this insect until 1914. Since that year the danger to elms in our towns and cities has caused the

city dweller to fear the canker-worm as the apple grower has feared it in the past.

Professor Geo. A. Dean, State Entomologist of the northern division of the state, reported to the State Horticultural Society, in 1915, as follows:

"The Spring Canker-worms killed more apple trees in Kansas in a single season than the San Jose scale has killed during its entire history as a pest in the state.

The injury done by the canker-worm is not confined to fruit trees, but they also attack a number of our most valuable forest and shade trees. Last Spring the elms over a large portion of the state were partly, and in many cases completely, defoliated by the Spring Canker-worm. The injury caused by this insect, in spite of the cool wet weather which followed the attack, killed a large number of elms. Many of the trees that were not killed were weakened, and thus rendered susceptible to the attack of wood borers."

Hundreds of letters concerning the canker-worms have been received by Professor S. J. Hunter, State Entomologist of the southern division of the state, and by Professor Dean. Numerous press reports have been issued during the past two years giving information regarding banding and spraying to control these insects, by Professors Hunter and Dean.

The more progressive property owners in many Kansas towns, and especially in Ottawa, Winfield, Lawrence, Manhattan, Topeka and Emporia, have made an effort to save their elms by banding or spraying, for the past two or three years. This work, while partially successful, has in most cases been incomplete and consequently has failed to eradicate the canker-worm.

In Lawrence a municipal campaign has been begun this year, by which it is hoped to entirely free the city of this pest, and demonstrate to other cities the need of organized effort in insect control.

PLATE I

Fig. 1. Spring Canker-worm eggs recently laid on bark. (greatly enlarged)

Fig. 2. Adult male, Paleacrita vernata Peck. (slightly enlarged)

Fig. 3. Female vernata moths on bark, showing protective coloration. (slightly enlarged)

Fig. 4. Adult female, Paleacrita vernata Peck. (slightly enlarged)

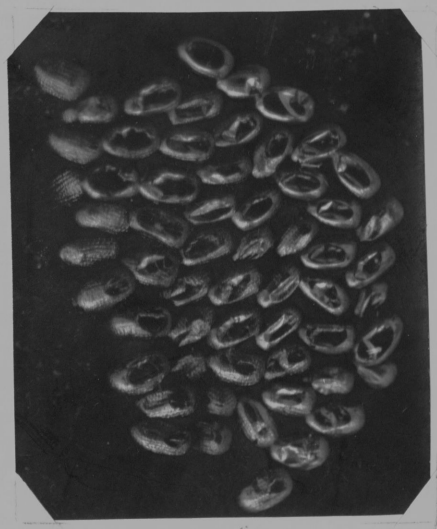
Fig. 5. The four instars of vernata larva. (slightly enlarged)

Fig. 6. Pupa of vernata. (greatly enlarged)

Fig. 7. Female vernata moth dissected to show number of eggs in ovaries. (slightly enlarged)

Fig. 8. Eggs shown in Fig. I, photographed shortly before hatching.

(Photographs by R. H. Beamer.)



LIFE HISTORY AND HABITS

The Spring Canker-Worm,

Paleacrita vernata Peck.

Imago.- As the name *vernata* indicates, the moths of this species issue from the ground in the spring for the most part. They begin to emerge in this latitude (39 degrees) during the first warm spell of weather in January and continue to come out until the middle of April. It is possible that a very few come out during mild weather in December or even in late November, since the adult moth is fully formed within the pupal case in late October, but we have no definite observations to prove their emergence earlier than January 5.

On that date several moths of both sexes were captured this year, on sticky bands which had been placed around elms at Professor Hunter's residence in Lawrence. On January 4 the minimum temperature was 33 degrees, this being the first day on which no freezing temperature was recorded since December 7, 1916. On January 5, 6, 7 and 8 the mean temperatures were 38 degrees, 42 degrees, 37 degrees and 43 degrees respectively, with freezing temperatures only in the early mornings. On January 8 we counted 350 moths on one band. Two days later the temperature dropped to 10 degrees and did not rise far above freezing for nearly two weeks.

On January 28 and 29 the temperature went as high as 64 degrees and the minimum was 34 degrees on the 29th. At this time the moths emerged by the thousands so it was difficult to count them on the bands. The temperature began to drop on January 31 and on February 1 and 2 it reached 12 degrees below zero, staying close to zero for five days. Just after this cold wave numerous moths of both sexes were found in the crevices of the bark on large elms and all those examined were living. It should be noted that during January and February only .49 inches of snow fell, this being the driest winter on record in Kansas.

During the two previous winters a few moths were noted in January emerging through the snow but no record was kept of their number.

The maximum emergence occurs during March in this latitude. This year, between March 10 and 20 myriads of fluttering males were in evidence at the street lights, battering against windows of lighted rooms, and around the trees. On approaching the larger elms at evening, an hour after sun-down, we would find the ground for several feet away from the base of the tree and the tree trunk so thickly covered with moths of both sexes that the whole surface seemed to be moving. As those on the ground gained the trunk, more seemed to ooze out of the ground to take their places. By ten

o'clock the emergence ceases on the cooler nights but on warm nights it continues until eleven and a few were seen crawling toward the tree at nine o'clock the next morning. For the most part, however, the moths of both sexes emerge from the ground between 7 and 10 P. M. and immediately start to move toward the nearest upright object, be it tree, telephone pole or hitching post. They usually are found to be more numerous on the northeast side of the tree. An electric pocket lamp brought near does not disturb them and is very useful in observing their actions.

As soon as the males' wings are expanded they begin to leave the ground and flutter around over the females. Copulation takes place this same evening, mostly after 9 o'clock, continuing long after the moths have ceased to emerge and have quieted down. Sometimes the male's body is over that of the female, their heads facing the same direction and the end of his abdomen curved downward over hers; but just as often the copulation takes place with only their caudal ends touching and the male and female facing in opposite directions.

It has been suggested by some that during copulation the males sometimes carry the females above the bands which have been placed around the tree trunks to arrest their upward progress. I have watched carefully for evidence of this and have taken copulating pairs from the tree and attempted to make the male fly

by throwing the pair into the air, but they always fell to the ground. The male does sometimes pull the female up the tree after him by using both legs and wings, but the sticky band stops them both.

At all times the males seem to be more numerous around the trees at night and an experiment was carried on by Mr. B. P. Young to ascertain the per cent of each sex emerging from a certain area of ground under an infested tree. Traps made of tight wooden boxes, open on the bottom only, were placed firmly on the ground and at intervals removed and the insects which had emerged beneath the trap counted. The results show 25 per cent females and 75 per cent males.

The egg laying does not begin until the next evening after copulation and in cold weather is postponed for several days or until warmer weather comes. Almost no eggs were deposited on the trees during January and the first part of February, but during that time the moths which were brought into the laboratory temperature soon oviposited. During the maximum emergence of moths oviposition begins the second night, and most of the eggs are laid during the first three nights of oviposition.

A total of 2600 females were brought into the University insectary by Mr. Young; 100 which were supposed to have copulated the night before were taken from the trees every morning for 26 days, beginning February 27.

A count was kept of the eggs laid each day, of the length of the egg period, and of the number of eggs which did not hatch. The females were kept in the insectary and the eggs after being counted each day were placed outside the building to secure normal outside conditions of temperature and moisture.

The results of these experiments show that the 2600 females laid 209,875 eggs, an average of 81 eggs per female. Of these eggs 21% did not hatch, leaving an average of 65 fertile eggs per female.

This number seems very low compared to the statement which is frequently made that a single female of this species may lay over 400 eggs, but it is possible that the low number of eggs this year is due to lessened vitality of the moths. The larvae were observed to leave the trees earlier than we expected last spring, after they had been feeding only three weeks and were not as large as they had grown to be the year before. Professor George A. Dean states that he also noticed, at Manhattan, the larvae leaving early before their growth was completed. Soon after a heavy rain (1.65 inches) which fell April 30, the larvae disappeared so we could scarcely find one a few days later.

The moths this year showed great variation in size, many females being only 5 to 6 mm. in length while the larger ones were 10 to 12 mm. in length. Last year a dozen female moths were taken at the base of a tree

and were dissected and the eggs counted. From the ovaries of these 12 moths 4816 eggs were taken; an average of 401 eggs per moth. One moth with distended abdomen was found to contain 676 eggs. This year three of the larger moths found at the base of a tree were dissected and an average of 352 eggs per moth was counted. Three of the smaller moths contained 294 eggs or 98 eggs apiece.

It seems possible that the moths produced from the under sized larvae of last year do not lay as many eggs as the moths from large, well-fed larvae, and this condition may be one of the obscure natural factors which cause the canker-worms to decrease and disappear for a series of years.

The female seeks a crevice or irregularity in the bark of the tree and thrusting her sharp, two jointed extensile ovipositor into the crevice she lays an irregular mass of eggs whose number and arrangement depend on the size and shape of the crevice. The layers of rough bark on the elm afford innumerable hiding places for the eggs but on smooth barked trees such as apple the females must seek some irregularity or break in the bark in which to hide them. We have found females as high as 25 feet up the trees ovipositing, but the majority of the eggs on elms seem to be laid on the larger branches and trunk.

The moths are nocturnal and during the day generally remain quietly tucked away in the crevices of the bark which they closely resemble in coloration. Being destitute of mouth-parts they do not feed, and live only a few days after oviposition is completed. Many of the males meet their destruction at the arc lights the same night they emerge. One of the strongest instincts of the female moths is that which impells them to climb upwards to oviposit. No repellant seems strong enough to turn them back downward. They travel readily across greasy bands or smooth surfaces, and struggle through cotton bands.

Egg.- The egg masses contain from 2 to 150 eggs but the average egg mass this year comprises about 45 eggs. These are laid with only enough of a glutinous fluid to fasten them slightly to the bark and to each other.

The egg is elongate-elliptical in shape, is 1 millimeter long and half as broad at the middle. The shell is opalescent, appearing sometimes to be tinted with yellow, green, or violet, and is generally corrugated, the longitudinal ridges being broken by cross furrows. When the embryo is nearly matured it can be readily seen curled around with head and caudal end together, and the egg-shell becomes more or less concave on the sides. A few hours before hatching, the egg, due to the color of the larva within, appears dark and bluish-

gray or olivaceous in color.

The larva eats through the shell on the side or end which is free from the surrounding bark and eggs, making a hole irregular in shape but just large enough to crawl out through. The remnant of the egg shell is opalescent and light in color like the newly laid egg.

The length of the egg stage varies with the temperature from 10 days at 72 degrees to 35 days at 45 degrees. With a mean temperature less than 45 degrees the egg period is prolonged and the eggs do not hatch until subjected to a higher temperature. A mean temperature of 72 degrees was, of course, only obtained in the laboratory.

The average length of the egg period this year under normal out of door conditions was 30 days with a mean temperature of 48 degrees. The great majority of the eggs were laid between March 10 and 20, and the most of the larvae emerged April 9 to 19.

Experiments carried on by Mr. Young in out of door cages at the University insectary show that out of 209,875 eggs none hatched on a day when the average temperature was below 48 degrees. The larva always waited until a day when the average temperature was 48 degrees or more before breaking the shell.

Larva.- On leaving the egg the young larva is 1.5 millimeters long and dark in color, with the head somewhat wider than the rest of the body. The head and shield are black, and the dorsal surface of the body dark olive-green, with a distinct central longitudinal white stripe which is broken by dashes of the general body color. On each side is a white stripe which includes the spiracles. The ventral surface of the body is a dark greenish-tan and the stout thoracic legs are a lighter green. There are two pairs of prolegs, one pair being on the ninth segment of the body and the other pair on the anal segment.

The larvae at once seek the leaf buds or expanding leaves for their first meal. In case the eggs were laid on the upper branches the larvae reach their food within a few minutes but those larvae which hatch from eggs on the lower trunk must travel some distance to reach the leaves of a large elm. Concerning this point the following note is taken from the writer's diary.

"April 5.- Larvae just hatched last night on my desk are all looping towards the light. They climb upwards when possible but those which climbed two feet up a dead twig to its end soon turned down and descended until they found an adjoining branch to climb. I timed one little looper and found that he climbed a foot in two minutes by continuous looping. They are very persistant in their searhh for food. Several of them went around a large glass jar five times before finding a branch touching the top of the jar on which they could climb. A larva hatching from an egg near the base of a large elm could undoubtedly climb to the leaves in a day and I have observed young larvae looping four days after hatching without having eaten."

The young larvae attack the unfolding leaf-buds, the blossoms and the fruit of the elm. At first they can only rasp the surface, but by the second day they eat ragged holes through the tissue. When the eggs hatched this year there were very few of the elm leaves expanded and the larvae bored holes through the side of many of the buds, feeding with their heads inside the buds and bodies extending outside the hole. Some larvae fed on the blossoms and later ate holes through the fruit but the majority sought the leaf-buds first.

After feeding 8 to 10 days the first moult occurs, when the larva is 7 millimeters long. The most conspicuous change is in the coloration of the head, which now becomes distinctly mottled with brown and white, instead of the solid black color which is characteristic of the first instar. The white stripes on the body now become darker and much less distinct.

The second moult occurred six days after the first in the case of one larva in the laboratory. At this moult the stripes almost disappeared and the color of the body became uniformly reddish-brown indistinctly spotted with gray. The spiracles and the tubercles on the next to the last segment were black. The head retained its distinct markings and the prothoracic shield was white. The larva was 12 millimeters long at the time of the second moult.

The third moult has not yet been observed by the writer, so a brief account of this moult is taken from Riley's Seventh Missouri Report.* "After the third (and I believe last) moult, the appearance changes but little. The full grown larva averages .9 inch (23 mm.) in length, with an average diameter of .10 inch, being broadest on joint 11. It varies from light fleshy-gray to almost black." The head retains its distinctive spotted appearance and the light prothoracic shield is present on both light and dark specimens.

The larvae feed voraciously on the leaves, at first eating small holes through them, so that to a person standing beneath the tree and looking upward the foliage appears to have been riddled with a shot-gun. As they near their full size the larvae eat the entire leaf except the midrib, and the tree appears as though a fire had gone through it, leaving it brown and lifeless.

The larvae in cold or wet weather seek the lower side of the leaf or in case the leaves are but partially expanded they creep within the bud for shelter and they feed little until warmer weather and sunshine appear. They feed and move about by day, remaining stationary during the night.

* Seventh Report of the State Entomologist. Page 82.

They have a curious habit of often resting in a stiff, straight posture at an angle of 45 degrees from the twig or leaf, holding on by the prolegs and always with a silken thread from the mouth attached to the twig. In this position they so resemble a branch of the twig that they often elude detection. In case the larva is disturbed he drops simultaneously from the twig and lengthening the silken thread from his mouth hangs suspended in the air a foot or so below the branch. If the disturber continues to bother him the larva lengthens the silken thread with successive drops, stopping an instant every few feet until he reaches the ground.

After the danger is past the larva fastens the silken thread to some object such as a weed or blade of grass, and sailor fashion, ascends the thread to the leaves again. In order to do this, he bends back his head and catches hold of the thread above his head with one of the legs of the third pair, then, raising his head, he seizes the thread with mandibles and fore legs, and, by repeating the same operations twisting from side to side as each step is taken, he reaches the top with tolerable rapidity.

In case the larva does not descend to the ground but remains suspended in the air a few feet below the branch, he regains the branch by a slightly different method, since the thread is secured at one end only. Bending his head to the side and holding the thread with

the fore legs and mandibles, he reaches up and winds the thread around the third pair of legs, repeating this action until the entire thread has been wound about his legs and he has regained the branch. Then he breaks off the thread from the coil about the third legs and stepping out of the coil walks away.

To add to their protection, the larvae, when attacked expell a dark colored, odorous liquid from the mouth much like that which a grasshopper expells.

When the larvae reach their full growth, after feeding from three to five weeks, they become restless and descend to the ground, either by looping down the trunk or by spinning down on a silken thread. Upon reaching the ground the larva seeks a suitable spot, generally within a few feet of where he descended, and soon begins to dig down into the earth with his mandibles, to form the pupal cell.

The larvae, while hanging suspended by their silken webs, are often blown by the wind into adjacent trees whose branches are several feet away. The bridge formed by their combined webs allows many other larvae to loop across, so that banded trees are quite often attacked by canker-worms from nearby unbanded trees. This often results in cities where a man bands his shade trees and his neighbors neglect to do so.

We have seen instances where the larvae, having stripped all the leaves from a tree, leaving only the

base of the midrib, descended to the ground, and marched by thousands, like an army, to the base of a tree over fifty feet away. They climbed to the leaves and began to feed. In one instance they marched to a scotch pine and ascending the trunk explored the branches. Finding no suitable leaves to eat they descended again and scattered out to seek places to pupate. It required nearly ten hours for this maneuver.

Pupa.- The larvae pupate in the soil from 1½ inches to 5 inches, but generally about 2 inches, below the surface, in uncultivated ground. In case the soil beneath the trees has been recently cultivated and it is loose, they sometimes go down 7 or 8 inches.

A larva which the writer observed in the laboratory dug a tunnel obliquely into the soil so that the tunnel was 3 inches long and the larva was 1½ inches below the surface. The larva, in digging, removed the particles of soil with his mandibles and bending the head backward over his body dropped the soil behind him filling up the tunnel above him as he proceeded; his abdomenal segments holding back the soil from falling into the tunnel which he was digging ahead.

Twenty-four hours after beginning to dig, the larva was found with the cephalic and caudal ends bent back over the dorsum of the body vertically, resting in

a simple earthen cell apparently unlined, but on close observation a few strands of silk were found to hold the soil surrounding the cell. Two days later the larva had decreased in length from 22 mm. to 12 mm. The head and dorsum of the body had turned black while the ventral surface had become light gray or nearly white. The larva no longer bent back the head and caudal end, but could lie in the cell almost straight. When disturbed it would whip the caudal end from side to side, and seemed incapable of locomotion by use of the legs or prolegs. The metamorphosis had evidently begun. Five days after beginning to dig the tunnel the chrysalis was complete.

The Spring Canker-worms enter the pupal stage between the last of April and the first of June and remain in the ground during the summer and autumn, emerging from January to April. We have found the moths fully formed in the pupal skin by October 21 and the metamorphosis may be completed even before that date.

THE FALL CANKER-WORM

Alsophila pometaria Harris.

As the writer has not observed the Fall Canker-worm, the following account of its life history is reproduced from an article* by Dr. W. E. Britton, State Entomologist of Connecticut.

"The adults of the fall species appear during the warm days of November and December, often occurring in great numbers on foggy days during a thaw after the ground has been frozen. In 1908, the first females were observed around the bands October 28th, and from that time on they increased in abundance, being more in evidence than the males up to November 20th, when the males were apparently much in preponderance. Many eggs were laid on the trees before the middle of November, and only a few males could be found. The females of both species are without wing, and must necessarily crawl up the trunks of the trees to lay their eggs on the twigs. Males, on the other hand, are provided with wings, and fly short distances at night and even during dark cloudy days. Many of the adults, however, do not emerge until March, and this is especially the case when the ground freezes early in the Fall and does not thaw out until late in the winter.

*Report of Conn. Agr. Experiment Station 1907-1908 Part XI, pp. 780-782.

'In Saybrook, where the elm trees were considerably damaged by canker worms in 1907, sticky bands were applied about March 1st, 1908, as it was supposed to be the Spring species that caused the injury; but it was found later that the Fall species was the more abundant and that enough eggs had already been laid before the application of the sticky bands so that the trees were quite badly eaten by canker worms.

'The eggs, though deposited in late Fall or in early Spring, hatch in Connecticut during the last of April or the first few days of May.

'The young larvae are at first very small, and they soon begin to feed on the tender unfolding leaves. They eat holes entirely through the leaves, or in fact devour all the green tissue, leaving nothing but the veins. Later, as the foliage becomes firmer and more leathery, they often leave the greater portion of the network, especially in case of the apple which turns brown in June and looks as if a fire had gone through the orchard.

'The caterpillars feed from four to five weeks, during which time they spin down on threads of silk when disturbed, and molt three times. They then go to the ground and transform to the pupa or chrysalid stage. By June 6th, 1908, all canker worms had gone into the ground to pupate. They then remain in the pupa stage until the late Fall, when the adults of the

Fall canker worm begin to emerge in November, and during warm days for two months they may be seen clustered on the trunks of trees; but some do not appear until March and April, at the same time that the Spring species comes forth. There is but one generation each year.

'Canker worms are always rather local in their attacks, and the writer has often seen large orchards defoliated in certain localities, while in adjoining towns no damage could be seen. During 1908, the most severe injury occurred near the coast, though the insect was present locally in the northern portions of the state."

FOOD PLANTS

The Spring Canker-worm.-- We have found apple, American elm, hackberry, plum, and honey locust more generally defoliated by the Spring Canker-worm than other hosts in Kansas. Next in importance as host plants come the cherry, apricot, wild crab, and among shrubs the rose and flowering almond. Some authors consider the canker-worms as general feeders, but during the three years in which this species has been abundant in Lawrence, they have not injured to any appreciable extent the trees of other species than those just named. There is present in eastern Kansas an abundance of soft maple, box elder, ash, oak, walnut, peach and catalpa, all of which are mentioned as food plants of the canker-worm, but we have found only an occasional leaf eaten on these trees, even in a locality where the American elms and hackberries were completely defoliated. The red elm or "slippery elm" is immune to attacks of the canker-worm.

The host plants on which the Spring Canker-worms have been found feeding, including those of which only a few leaves were eaten, are as follows:

*Almond, Flowering (Amygdalus communis)

*Apple (Pyrus malus L.)

*Apple, Wild Crab (Pyrus ioensis).

*Apricot (Prunus armeniaca)

Ash (Fraxinus americana L.)

*Birch (Betula alba L.)

*Box Elder (Acer negundo L.)

Catalpa (Catalpa speciosa Warder)

*Cherry, Cultivated varieties (Prunus cerasus)

*Cherry, Wild Red (Prunus pennsylvanica L.f.)

Chestnut (Castanea dentata Barkh.)

*Elm, White (Ulmus americana L.)

*Elm, Water (Ulmus americana L.)

*Hackberry, Northern (Celtis occidentalis L.)

*Hickory, Pignut (Hicoria glabra Britton)

*Hickory, Shagbark (Hicoria ovata Britton)

*Haw, Red (Crataegus sp.)

Linden (Tilia americana L.)

*Locust Honey (Gleditsia triacanthos L.)

Maple, Silver (Acer saccharinum L.)

*Oak, Chestnut (Quercus muhlenberii Engelm.)

*Oak, Pin (Quercus palustris Du Roi)

*Oak, Bur (Quercus macrocarpa michx.)

*Oak, Red (Quercus rubra L.)

*Peach (Prunus persica L.)

*Pear (Pyrus communis L.)

*Plum, Cultivated varieties (Prunus sp.)

Privet, Common (Ligustrum vulgare L.)

Quince (Pyrus cydonia L.)

*Rose, Cultivated varieties (Rosa sp.)

*Rose, Prairie (Rosa setigera)

*Walnut, Black (Juglans nigra L.)

*Willow, (Salix spp.)

The Fall Canker-worm.--The apple and elm are given as the principal food of this species in New England with chestnut, oak, pear, hickory, box elder and maple as secondary food plants. Essig states that in California the food plants include "the fruit and foliage of the apple, apricot, cherry, elm, maple, plum, prune and other fruit trees. The foliage of many forest and ornamental trees are attacked."

*Observed by the writer.

NATURAL ENEMIES

The enemies of the canker-worms which are provided by Nature as a check on their too great increase are principally three; unfavorable weather, birds, predaceous and parasitic arthropods.

Unfavorable weather is by far the greatest check upon them. Excessive moisture at the time of their emergence from the soil weakens some of the moths, expecially the males, and seems to prevent to some extent the fertilization of the females, thus reducing the number of fertile eggs laid. The great danger to the canker-worms, though, is excessive rainfall during the larval or feeding period. Many larvae are washed from the trees during a heavy rain and, although some of these regain the limbs by climbing the trunk, a large number disappear. This is especially true of young larvae in the first and second instars. During rainy weather the larvae eat little and consequently their development is retarded. They seem to be unharmed by frosts which are severe enough to injure potato and tomato plants.

We have found this year what seems to be a wilt disease killing some of the larvae at Baldwin and Lawrence. It was found after a week of rainy weather

and seemed to attack larvae of all sizes, causing them to turn black and die. Those which had died recently were soft and internally mostly liquid, but only the shrivelled and hardened integument remained of some. This may be the same disease as that described by Peck* which he says "may be called Deliquium." He states that; "In this disease the whole internal structure is dissolved into a liquid, and nothing is entire but the exterior cuticle, which breaks on being touched."

Next to unfavorable weather, the birds are our most important natural enemies of the canker-worms. Probably no insect is a favorite food of more species of birds than the canker-worm larva. It lives exposed on the outside of twigs and leaves where the birds can easily secure it, and is without distasteful hairs or spines on its integument. The English sparrow, which is said to have been imported into America to check the ravages of this insect, is no doubt our most efficient canker-worm eater in the cities. We have watched these much despised birds picking larvae from the elms at all hours of the day from early morning to twilight and even during rains. The robin is also an efficient destroyer of canker-worms, especially of the moths which are found at the base of the tree. The writer has seen

*See Extracts from Peck's Essay on the Canker-worm in Historical Notes.

flocks of bronze grackles alight in the tall elms in Lawrence and moving from branch to branch, noisily devour great numbers of larvae. Having exhausted the supply on one tree they moved in concert to another tree to continue the feast.

Many of the more timid birds which are not so commonly found in the cities as the English sparrow and robin are just as efficient enemies in the country.

Mr. C. D. Bunker, Curator of Mammals in the Dyche Museum, secured a hundred birds from a grove four miles from Lawrence and carefully estimated the percentage of canker-worm larvae found in their stomachs. They were taken near the edge of the timber where they could easily have returned from the surrounding fields with other food, and the grove is composed of several species of trees only a small percent being elms infested with canker-worms. Mr. Bunker has kindly permitted the use of the following list which gives the percentage of canker-worm larvae found in the stomachs of the hundred birds.

Arcadian Fly-catcher	75%
Baltimore Oriole	75%, 50%
Black-polled Warbler	100%
Black-billed Cuckoo	95%
Blue Bird	10%, 75%
Blue Jay	75%, 85%

Bronzed Grackle	50%, 10%
Brown Thrasher	50%
Catbird	100%, 85%
Chickadee	100%, 100%, 100%, 100%, 50%
Chipping Sparrow	100%, 100%, 100%, 5%, 100%
Cow-bird	0%, 85%, 5%
Crested Fly-catcher	75%, 50%, 95%, 10%
Crow (young)	75%
Dicksissel	100%, 100%, 85%, 5%, 90%, 5%
Downy Woodpecker	75%
English Sparrow	100%, 85%
Golden-crowned Kinglet	0%
Gold Finch	0%, 0%
Green Heron	0%
Grey-cheeked Thrush	100%, 50%
Hairy Woodpecker	30%, 10%
Indigo bird	100%, 100%, 100%, 100%
Kingbird	30%, 50%, 95%, 100%, 75% 90%
Lincoln Sparrow	85%, 100%
Northern Yellow-Throat	100%, 75%, 100%
Northern Warbler	95%.
Nut Hatch	10%
Olive-backed Thrush	100%
Orchard Oriole	100%, 100%, 60%, 95%

Red-headed Woodpecker	100%,	85%		
Red-winged Blackbird	100%,	60%		
Robin	25%,	100%		
Rose-breasted Grossbeak	75%			
Tennessee Warbler	100%,	100%,	100%, 100%,	100%, 100%
Titmouse	25%,	35%		
Yellow-billed Cuckoo	50%,	75%,	75%,	90% 50%
Yellow-breasted Chat	25%,	10%		
Yellow Warbler	95%,	75%,	100%, 100%,	85% 100%

Of the 39 species listed, 18 species had at least one specimen whose stomach contained 100% canker-worms.

In addition to Bunker's list the following birds are mentioned by Riley as canker-worm eaters: Butcher-bird, House Pigeon, Red-eyed Vireo, Song Sparrow, Scarlet Tanager, Wood Pewee, Least Pewee, Wilson's Thrush, Black and White Creepers, Maryland Yellow-throat, Nashville Warbler, Golden-crowned Thrush, Chestnut-sided Warbler, Black-and-Yellow Warbler, Prairie Warbler, Canada Warbler, Red-start, Cedar-bird, Purple Finch, White-winged Cross bill, Bob-o-link, Golden Robin and Summer Yellow-bird.

We find that a total of 62 species of birds have been found with canker-worms in their stomachs and it is probable that this list is not complete.

A bird may eat many insects in a day. It is stated by Mr. Beal in the 1908 Yearbook of the United States Department of Agriculture that "from 3,000 to 5,000 insects have been found in a bird's stomach at one time", and as a bird's digestion is rapid, many times its stomach capacity are eaten in a day. Professor Forbes shot seven specimens out a flock of thirty cedar birds in an orchard infested with canker-worms. The stomachs of all these were full of worms, averaging 100 each. Mr. W. R. McIntosh, of Fresno, California, found that "the breakfast of four chickadees consisted of 1,028 eggs of the canker-worm, and four others had eaten 600 eggs and 105 mature insects."*

The writer has frequently seen a flock of chickens beneath an apple tree greedily devouring every canker-worm moth or larva which came within their reach. Young chicks are especially fond of the worms dangling on their threads near the ground.

Several insects are reported as preying upon the canker-worms. Harris states that they are eaten

*2nd Biennial Report Commission of Horticulture, Cal. P. 537.

by the large green ground-beetle, Calosoma scrutator, which appears about the time when the larvae begin to leave the trees, and runs about in the grass after them or mounts the trunk to seize them as they come down. Riley adds the black ground-beetle, Calosoma calidum Fabr., as a canker-worm eater.

The Fraternal Potter-wasp, Eumenes fraterna Say, according to Harris, stores her cells with canker-worms, often gathering eighteen or twenty of them for a single cell.

Riley states that the most common parasite found in Missouri infesting the larva of the Spring Canker-worm is a small, four-winged fly (Microgaster paleacritae Riley). About 10 per cent of the worms which he tried to rear were destroyed by this parasite. The parasite larva after issuing from its victim spins a pale, greenish-white cocoon alone, and not in company. The flies issue in May. Harris mentions a Tachinid fly whose maggot infests the worms and destroys about one-third of them in Massachusetts. The maggots live singly within the bodies of the canker-worms till the latter die from weakness.

The eggs of the Fall Canker-worm are parasitized by a minute chalcid fly (Platygaster sp.) which is said to have been very common in Connecticut. The eggs are also devoured by a mite, Nothrus ovivorus, Pack.

Many spiders feed upon the bodies of the moths which have been caught by the tanglefoot bands and upon the eggs laid below the bands. The spiders' webs often become so numerous over the bands that moths are enabled to cross on the bridge thus formed.

Riley states that hogs are very efficient in rooting up and devouring the chrysalids during the summer months.

PLATE II

Fig. 1. Burning moths from tanglefoot bands with blow torch.

Fig. 2. Early injury to leaves by Canker-worms.

Fig. 3. Final injury to leaves by Canker-worms.

Fig. 4. Moths caught on tanglefoot band in one night.

Fig. 5. Section of same at close view.

Fig. 6. A season's catch on wide bands of tanglefoot.

(Photographs by R. H. Beamer.)

CONTROL MEASURES

There are three general methods employed by man in fighting against the canker-worms; first, preventing the female moth from climbing the tree to lay her eggs; second, spraying to kill the larvae; third, cultivating the soil to kill the pupae.

1. Preventing the wingless female moth from climbing the tree to lay her eggs.

As soon as it was learned that a wingless moth, which climbed up the tree trunk from the ground, was the cause of so many caterpillars devouring the foliage, men began to invent devices for arresting her ascent from the ground. The devices recommended as early as 1797 are given by Samuel Deane in the following account.*

"This worm is produced from the eggs of an earth-colored bug, which having continued under ground during winter, passes up on the bodies of apple trees early in the spring. They are hatched as early as the end of May, and are so voracious that in a few weeks they destroy all of the leaves of a tree, prevent its bearing for that year, and the next, and give it the appearance of its having been burnt. As the perspiration of trees is stopped by the loss of their leaves, they sicken and die, in a few years.

*The Newengland Farmer or Georgical Dictionary, 1797.

'The worms let themselves down by threads in quest of prey, like spiders; by means of which the wind blows them from tree to tree; so that in a close orchard not one tree will escape them. But trees which stand singly are seldomer infested with these insects. As they are the most pernicious kind of insects with which Newengland is now infested, if any person could invent some easy, cheap, and effectual method of subduing them, he would merit the thanks of the publick, and more especially of every owner of an orchard.

'Several methods have been tried, with some degree of success; 1. Tarring. A strip of canvas or linen is put round the body of a tree, before the ground is open in the spring, and well smeared with tar. The females, in attempting to pass over it, stick fast and perish. But unless tarring be renewed every day, it will become hard, and permit the insects to pass safely over it. And renewing the tar in season is too apt to be neglected, through hurry of business and forgetfulness. If birdlime were to be had, it it might answer the purpose better, as its tenacity will continue for some time. 2. Some tie straw round the bodies of the trees. This serves to entangle and retard the insects, and prevents the ascent of many of them. But they are so amazingly prolifick, that

if ever so few of them get up, a tree is greatly damaged, at least for an ensuing season or two."

Not satisfied with the unsuccessful results secured by the early investigators, many later horticulturists and entomologists have sought to improve the barriers against the moths. Riley * gives an excellent account of the barriers in use as late as 1882.

"Numerous indeed have been the devices-patented or unpatented-which have at different times and in different parts of the country been used to accomplish the desired end; and every year our agricultural journals report individual experiments with some one or other of these devices--some favorable and others adverse. Those most generally in use have consisted of some application of a sticky nature to the trunk of the tree, whereby the feet of the moth may be encumbered and from which she may be unable to escape. Various substances have been used for this purpose, of which I will mention tar, bird-lime, refuse sorghum molasses, printers' ink, slow-drying varnishes, and melted india-rubber; this last always retaining its soft viscid state, while the rest become dry and hardened by exposure to the air.

*Third Report of U. S. Entomological Commission, 1883, Pp. 183-191.

'The editor of the New England Farmer thinks that oil and rosin, boiled together in certain proportions, which have to be ascertained by "the rule of the thumb", answers a better purpose than tar, because it does not dry up so much on hot days, and therefore does not require to be renewed every day, as tar does.

'The methods of application of these substances have been as diverse as the substances themselves. They have been applied either directly around the body of the tree, or over a broad belt of clay-mortar, or on strips of old canvas, on sheep-skin, on stiff paper, on the under side of a horizontal and close-fitting collar of boards fastened around the trunk, or on four boards nailed together, like a box without top or bottom, around the base of the tree, to receive the application on the outside.

'Whatever substance is used must be renewed as often as it becomes dry or as the surface ceases to be sticky or becomes coated with a mass of captured moths.

'It cannot be denied that it requires a great deal of time, labor, and expense to continually renew these applications on every tree in large orchards during so many months of the year. That it will pay to do this work in orchards where the Canker Worm is known to be numerous, there cannot be the least doubt. The old adage, "What is worth doing at all is worth doing well", was never truer than in fighting this insect.

'Another remedy, calculated to prevent the moth, and the larva as well, from ascending the tree, is the use of a trough to contain some substance, usually of an oily nature, which kills the insects as they come in contact with it. These troughs are made of tin, lead, rubber, iron, or other substances. The principal objections to their use are their cost, the difficulty of fixing and keeping them in their places, and the injury suffered by the trees when their contents are washed or blown out and fall on the bark. --Care should be taken to renew the oil as often as it escapes or becomes filled with insects.-- If oil troughs are used, it will be found much safer and surer to sink them in the ground close around the butt of the tree than to wind them around the trunk higher up. There will be no chance for the young worms to get up between the trough and the tree, and all danger of hurting the tree with oil or tar is entirely avoided.--

'Belts of cotton wool have been used to entangle the feet of the moths, and collars of tin plate, fastened around the trees and sloping downwards like an inverted funnel, have been proposed, upon the supposition that the moths would not be able to creep in an inverted position beneath the smooth and sloping surface."

The barrier most highly recommended, by Riley, above all other bands, is the hanging tin band described by him in the following account:

"This hanging tin band was first described in the Cultivator and Country Gentleman for May, 1873, and afterward in the Illustrated Annual Register of Rural Affairs, published by Luther Tucker and Son, of Albany, N. Y., and is very favorably spoken of by that careful horticultural writer, Mr. J. J. Thomas. It has been used successfully by C. L. Jones of Newark, N. J., and we should advise the use of it, if kept properly oiled, over all forms of troughs whatsoever, for they too often get filled up with the dead bodies of the moths or with leaves, or get bridged with spider-web; and where fastened directly around the tree must needs be renewed as the girth of the tree increases. -----the contrivence---consists essentially of a band or circle of tin, a few inches outside the trunk of the tree, and held there by a circle of muslin, attached to the tin at its edge and drawn with a cord at the top, so as to fit the tree closely and prevent the insects from getting up without going over the tin, covered with a mixture of castor-oil and kerosene; as soon as they touch this, they drop to the ground. ---the union of the tin and muslin is effected by turning over the upper edge of the tin before it is bent to a circle, inserting the edge of the muslin, and hammering them together. The tin may be about three inches wide, and long enough to rest three or four inches off from the trunk, when bent around in the form of a hoop, and secured by rivets or

small tacks. After the tin and muslin are attached to the tree, the whole inner or lower surface of the tin is daubed with a mixture of equal parts of kerosene and castor oil. The tin and muslin entirely protect the oil from the sun and weather, and it will not dry for several days. It will not run down, as the castor-oil thickens it. Of course it needs occasional renewal, with a small brush or feather---

'But I would remind the reader that even so perfect an "estopper" as this may measurably fail if directed solely against the moths. The worms that hatch below the trap, and which are more difficult to manage, must also be headed off; and I would insist, in pursuance of this object, that, in addition to the directions given for its use, the muslin be tied around the tree over a layer of cotton wadding, and that the contrivance be kept on the tree and the tin oiled at least three weeks after the tree begins to leaf out in the spring. The eggs laid below the trap should, of course, be destroyed as far as they can be, and such destruction in dealing with the spring species will be facilitated by a bandage of rags below the trap, or by anything that will afford the moth shelter for her eggs and that can be easily removed and scalded; where no such lure is used, an application of kerosene will prevent the eggs laid on the trees from hatching. But some are likely to be laid where they escape the closest

scrutiny, and while the precautions I have indicated will insure against the ascent of such, whether from the Fall or Spring species, without those precautions some of the newly-hatched worms, which can pass through a very minute crevice or over the smoothest surface, may get into the tree; and though they may be so few in numbers as to attract no attention, they nevertheless perpetuate the species in the orchard."

Dr. W. E. Britton, who has done some excellent work in controlling the canker-worms in Connecticut, adopted the sticky band as the most practical type, as early as 1896.* "Tests of various substances were made and it was found that printers' ink was about as satisfactory as anything that could be obtained for the price. Odd and ends of ink, consisting of various colors left over from job work, were sold under the name of "tree ink" at a lower price than that usually charged for printers' ink, and this is just as good for the purpose. It will harden, however, after a short time, and it was found that by mixing it with a non-drying petroleum oil it could be kept longer in a viscid state. The oil could also be applied with a brush to the bands from time to time to keep them in proper condition. Pine

*Conn. Experiment Station Report 1907-1908.
Part XI, page 791.

tar and a preparation called caterpillar lime caused injury to some small trees, even when applied to a band of tarred paper."

The "tree ink" was described by Dr. Britton in 1900. "Since then", he says in 1907, "a substance known as 'tree tanglefoot' has been placed upon the market, and though this is a proprietary article, it is difficult to make anything for the price that equals it. It remains sticky for a long time and causes no injury to the tree, even though applied directly to the bark."

Tree tanglefoot has been used extensively by the United States Bureau of Entomology in the control of the Gipsy and Brown-tail moths in New England for ten years. Messrs. Rogers and Burgess, in charge of that work, stated in 1910 that success in using the sticky bands to prevent the ascent of the caterpillars was not attained until tree tanglefoot came into use, about 1905.

One of the best home made banding materials yet found by the writer after numerous experiments is one originated by Mr. Geo. E. Fisher, of Freeman, Ontario and described in the Report of the Entomologist and Botanist of the Canadian Department of Agriculture, 1908. His formula is as follows: "For warm weather 3 pounds of caster oil and 5 pounds of resin. In cold weather use equal parts of both by weight." This mixture must

be heated slowly until all the resin is melted, and should then be painted directly on the bands while warm. The first application will not remain sticky very long as it is absorbed by the band or bark, but later applications remain sticky several weeks. It may be applied while warm with a large paint brush. Experiments are now being carried on to find a cheaper oil, such as the road oils, which will be as satisfactory as castor oil and may be substituted for it.

Banding materials which are more greasy than sticky do not stop the canker-worm moths. Such materials are excellent to prevent the larvae from ascending the trunks but the female moths will go across any surface which does not absolutely hold them fast.

The material recommended by Professors Hunter and Dean and used more than any other in Kansas is tree tanglefoot. It is a proprietary article and somewhat expensive, costing from 20 to 25 cents per pound in large quantities; but one pound will do for an application on five trees so the cost is not prohibitive when it is to be used on shade trees.

The method of applying the tree tanglefoot which is most generally used in Kansas and has been used in other states as well, is to spread it on a band of tarred paper. Some prefer a heavy manila paper but the tarred paper band is more durable, neater in appearance, and may be used two seasons without removing from

the tree. The tanglefoot is sometimes applied directly to the bark, which is first made smooth by cutting off the rough outer layers, but since this method leaves a disfiguring mark on street trees for many years and sometimes endangers the life of the tree when the bark is cut away carelessly, the durable paper bands seem more desirable.

The roll of tarred paper as secured from the dealer may be sawed into rolls 5 or 6 inches wide, this being the width of the band when placed on the tree. Since the bark of most of the shade trees attacked is rough, provision must be made for filling up the crevices between the band and tree to prevent the moths from crawling through. We have used cotton and the waste material from a mattress factory for this purpose. The cotton should be cut into strips slightly narrower than the paper so that the former will not be seen when the band is in place. A roll of cotton batting may be cut into rolls 3 or 4 inches wide with a pair of shears without unrolling the cotton, and thus save much extra labor in cutting. The 5 inch strip of paper is then unrolled, a line of glue applied along the middle and the 4 inch cotton strip unrolled over the glue. The band of paper with the cotton stuck to the inside may then be rolled up again and is ready to be placed on the trees. Rolls 25 feet long are the most convenient size to handle.

The most convenient method for securing the bands tightly around the trees is by the use of short large-headed roofing-nails. The men putting on bands can work in pairs to advantage. One man holds the end of the band while the other carries the roll about the tree and with one hand presses the band snugly to the bark. The band is then pulled fairly tight and held by one man while the other drives two nails into the overlapping ends, one nail slightly above the center and the other about as far below. In case the trunk has large depressions the band must be pressed snugly into these and nailed there. The nails used are just long enough to go through the overlapping ends of the band and cotton, and to hold firmly in the bark. They should not be driven in too tightly or the paper will break and the nails will be difficult to remove when the band is no longer needed. Before nailing the ends the roll should be cut with a knife leaving the band long enough for the ends to overlap about 2 inches. The cotton can be torn and the end tucked back beneath the paper then the nails driven in. The bands are easiest nailed on about the height of a man's chest and are then above the reach of small children and dogs. In the case of trees with extra large rough ridges of bark it is necessary to put extra cotton into the large crevices or to cut away the larger ridges of bark with a hatchet or draw-knife.

The tanglefoot should be applied with a wooden paddle about 1 1/2 inches wide in a strip around the lower part of the band at first so that later applications may be put on above it. Thus the older, less sticky material must first be crossed before the fresh material is reached by the moths, and this keeps the fresh tanglefoot from being crowded with moths so quickly. The tanglefoot band need not be wider than 1 1/2 inches to catch the early moths which come out before March.

In March, when the main brood of moths appears, the line of tanglefoot should be widened to nearly the width of the paper band and a second band should be placed on the trees around which the moths are known to be exceedingly numerous. As the moths begin to climb the trees in great numbers they are caught on the bands by the thousands and their sisters climb over their bodies until they reach the tanglefoot above. In seeking the females the male moths also are caught in the tanglefoot and their spread wings sometimes cover up the sticky surface quite rapidly in the case of large broods of the canker-worms.

After experimenting with combs and other instruments for removing the moths from the surface of the tanglefoot we found that the most practical method is to burn the insects off with a painter's gasoline blow-torch. This work can be done rapidly and, at

that season of the year, painters who are quite expert at this work may be readily employed. Holding the torch in one hand the workman passes around the tree, following with a wooden paddle in the other hand to stir up the tanglefoot.

During a warm spell following a few days of cold weather in March the moths may emerge in such great numbers for a few days (10 days this year) that it will be necessary to visit the bands every day, and renew the tanglefoot by burning off the moths and applying new tanglefoot over the old; but most of the time, during which the bands must be tended, once a week is often enough to visit them.

When their upward course is stopped by the bands some of the moths deposit their eggs in crevices of the bark between the bands and the ground. To avoid this we thought of placing the bands around the bases of the trees near the ground but there are many objections to this. The large roots make the trees very uneven in shape near the ground, leaves and papers blow onto the bands and ladies skirts brush against them. It has been suggested that the base of the tree below the band may be sprayed with kerosene to kill the eggs, after the most of the moths have come up, but this can be safely done only on thick rough barked trees. We have found that on the average elm tree very few of the young larvae ever crawl through the cotton and get above the band. They seek to cross the tanglefoot and are caught or drop to the ground and seek other trees.

The bands should be kept fresh as long as the larvae are feeding anywhere. They may be blown or washed by rains from a tree top and their webs broken so they must regain the branches by climbing the trunk of the same tree or some other tree. They may be carried on passing vehicles or persons for hundreds of feet or even miles until they drop off and seek to climb some tree for food. Unless it is windy and they are blown from the tree the full grown larvae seem to descend to the ground to pupate generally by way of the trunk of the tree. These larvae should by all means be caught and thus prevented from becoming moths.

The bands were needed from December 1 to June 1 this year because the moths emerged for so long a period and the larvae matured so irregularly, and it is probable that such may be the case quite often in Kansas. In case the Fall species were present the bands would have to be in place by the last of October.

We found that the tarred paper bands could be put on the trees more economically and satisfactorily by gangs of 4 men each. Two men work on each side of the street banding every elm, and every tree or pole which might allow the moths to reach the elm branches, as they go. A similar gang works on the next parallel street, starting at the same point.

For the two gangs on adjacent streets, one supply wagon or cart is necessary. The 25 foot rolls of banding are packed in burlap sacks, 10 or 12 rolls in a sack, and each pair of men carry one sack with them. When a sack is empty a new one can be obtained from the supply cart.

After the bands are all in place the tanglefoot is applied by 2 men on each street, one man working on each side, and each man carrying a 10-pound pail of tanglefoot.

A gang of 4 men will band 350 trees in 8 hours and 2 men will apply tanglefoot to 250 trees in the same time.

2. Spraying to Kill the Larvae.

The spraying of apple trees with Paris green to kill the canker-worms was first recommended in 1873 by Dr. William Le Baron, State Entomologist of Illinois. This poison was found to destroy not only the canker-worm but the codling moth as well, and with this discovery began a new era in apple growing. Since it has become the general practice to spray fruit trees each Spring for other insects, the canker-worm is no longer considered a formidable fruit tree pest. Banding is no longer recommended for orchard trees.

The spraying of large shade trees in cities is not practised, however, except as a last resort, in

case of insect attack. Spraying seems to be the only efficient method yet found for combating the Gipsy and Brown-Tail moths of New England, and the Elm Leaf-beetle, but when this spraying is done in close proximity to buildings it is difficult to protect paint from discoloration by the poison and it is said to be dangerous to use cistern water secured from roofs on which the poison has fallen. Because of the cost of proper spraying machinery and the objections just stated it seems advisable to employ banding rather than spraying to combat the canker-worm in our Kansas cities.

Paris green for spraying fruit trees has been largely displaced by arsenate of lead. Mr. F. C. Moulton, while experimenting with insecticides for the control of the Gipsy Moth in Massachusetts, prepared the first arsenate of lead in 1892, and found it did not burn the foliage as Paris green did when used strong enough to kill the caterpillars. This advantage as well as its greater adhesiveness has caused arsenate of lead to be used more than Paris green.

The formula most generally recommended in spraying for the canker-worms is 2 1/2 pounds of arsenate of lead paste, or 1 1/4 pounds of the powdered form, in 50 gallons of water, to be applied as soon as the leaves unfold in the Spring. It is well known that

the young larvae just beginning to feed are much more easily poisoned than older larvae, yet a good many fruit growers omit the "cluster cup" spray (applied after the leaf clusters have opened but before the blossoms have opened) and depend entirely on the codling moth spray to kill the canker-worms which are often half-grown by the time this spray is applied. Consequently we frequently receive reports that the arsenate of lead has not killed the canker-worms. Some growers who have waited until the larvae are large before beginning to spray have reported that two sprayings with poison did not kill the worms.

Owing to the resistivity of the canker-worms to arsenic, several investigators in California have had greater success in spraying with "Black Leaf 40", 1 to 1000 with 2 pounds of soap added to every 50 gallons of spray. The writer has tried this only on a very small scale but it seemed to be a very effective killing agent when sprayed on small elms infested with canker-worms.

As it is generally advisable to use the "Black Leaf 40" in the cluster cup spray for aphids, regardless of canker-worms, the latter may also be destroyed by it when they are present.

Spraying with arsenicals when the larvae are full grown will, of course, do no good, because the larvae descend to the ground and pupate without eating

the poison. "Black Leaf 40", about 1 to 900, might be used to save trees or shrubs suddenly attacked by the larvae which have come from other trees.

3. Cultivating the Soil to Kill the Pupae.

"Some persons", writes Harris in 1852, "have recommended digging or ploughing under the trees, in the autumn, with the hope of crushing some of the chrysalids by so doing, and of exposing others to perish with the cold of the following winter."

Thirty years later, Riley states that many orchardists still condemn plowing as of no avail against the canker-worms and he adds the following explanation.*

"The Spring Canker Worm, with its chrysalis formed in a simple earthen cavity, will be very materially affected by late Fall plowing of the soil, especially if the soil be of such nature as to crumble easily; for I have proved by experiment that whenever this fragile cocoon is disturbed or broken open in cold weather, as it very readily is by disturbance of the soil, at that season the chrysalis has not the power to penetrate the ground again or to form a second cavity, and in the great majority of instances either rots, dries out, becomes moldy, or, if on the surface, is destroyed by birds.

*3rd Report U. S. Entomological Commission. P. 195.

'Even summer plowing, if performed after the first of July would work beneficially; and it is for this reason, that clean, well-cultivated orchards are more free from the attacks of this insect, than slovenly and neglected ones. The only advantage of late Fall plowing lies in the facts that the chrysalis is at that time too benumbed to work itself into the ground and form another cell, and that birds are then harder pushed for food, and more watchful for any such dainty morceau.

'With the Fall Canker Worm, on the contrary, these measures will avail little, if anything; for the cocoon, composed of a thick layer of yielding silk strengthened by the interweaving of particles of earth, cannot be broken open by any such processes, and a dozen plowings would not expose a single chrysalis. Without doubt we have in these facts a valid explanation of the contradictory experience as to the value of Fall plowing or the use of hogs in an orchard as canker-worm checks."

Various measures of control such as plugging sulphur in the trunk of the tree, white-washing the trunk or covering the ground at the base of the tree with lime or ashes, and even giving the tree a dose of calomel, are almost too absurd to mention, yet intelligent citizens have used these measures within the last two years.

PLATE III

Fig. 1. Apple tree defoliated this year by Canker-worms.

Fig. 2. Elm defoliated last year by Canker-worms.

Fig. 3. Flowering almond (in foreground) completely defoliated by *vernata* larvae, climbing rose (in background) partially defoliated by *vernata* larvae.

Fig. 4. Honey locust nearly defoliated by *vernata* larvae.

Fig. 5. Elm shown in Plate II, Fog. 4, successfully protected from an extremely heavy infestation of *vernata* by tanglefoot band.

Fig. 6. Street of elms in Lawrence protected by tarred paper and tanglefoot bands.

(Photographs by L. M. Peace.)

SUMMARY

Historical:

Although the name "Canker-worm" is of European origin and was used as early as 1530 in England, the two species of geometrids known as the Spring and Fall Canker-worms are confined to North America and our first reference to either of these species seems to have been made in 1661. The Spring Canker-worm, Paleacrita vernata, was described by Peck in 1795 and the Fall Canker-worm, Alsophila pometaria, by Harris in 1852.

Description:

The principal differences between the two species are: The adult moths of the Spring Canker-worm have rows of stiff reddish spines on their backs and the Fall species have not. The eggs of the Spring species are shaped like a hen egg and are secreted in irregular masses in crevices of the bark but the eggs of the Fall species are shaped like a flower-pot and are laid in regular masses on the bark. The larvae of the Spring species have only two pairs of prolegs and those of the Fall species have three pairs of prolegs. The pupa of the Spring species is enclosed in a simple earthen cell which is easily broken while the pupa of the Fall

species is enclosed in a tough silken cocoon which cannot be broken by plowing.

Distribution:

The Spring Canker-worm is found from Maine to Virginia on the Atlantic coast, from the north Atlantic coast west to Colorado and in the Mississippi valley south to Texas. It is also found in California and Canada.

The Fall Canker-worm is common in Canada and throughout the northeastern United States as far west as Ohio and as far south as New Jersey. It is also in California and has been reported from Colorado.

The canker-worms are transported in the larval stage on people, trains, automobiles and other vehicles to new localities and in the egg stage on nursery stock.

In Kansas the Spring species was present before 1873 but did not become noticeably injurious before 1879. Since then it has spread to all parts of the state, the western portion being the last to be infested. There have veen several periods of severe canker-worm injury in orchards and during the last few years the shade trees in many Kansas cities and towns have been severely attacked.

Life History:

The Spring Canker-worm moths are fully formed within the pupal case by the last of October and they begin to emerge during warm spells in the winter, at least as early as January 5. The emergence continues until April. The eggs are laid in crevices of the bark and hatch in about four weeks, the time varying with the average temperatue. The larvae feed upon the leaves, blossoms and fruit of the host plant until after moulting three times, they reach their full size, which requires from 3 to 5 weeks, the larvae developing faster in warm, dry weather. The majority of the larvae leave the trees by the last of May and dig into the soil from 1 1/2 to 6 inches to pupate. They remain in the pupal skin until the next winter.

The Fall Canker-worm has a very similar life history; the main difference being the time of emergence of the moths and consequently the length of the egg stage, which lasts all winter.

Food Plants:

The Spring Canker-worm feeds principally on apple, American elm, hackberry, plum, honey locust, cherry, apricot, wild crab, rose and flowring almond. It has been reported as feeding on 30 different species of host plants.

The Fall Canker-worm is said to feed principally on apple and elm in New England, and on cherry, plum, and other fruit trees also in California. Chestnut, oak, pear, hickory, box elder and maple are also given as food plants of this species.

Natural Enemies:

Wet weather during the moth and larval stages is the greatest natural check on the canker-worms. A wilt disease may attack the larvae, following wet weather, and kill many of them. Next to unfavorable weather, the birds are most important as enemies of the moths, eggs and larvae. The worms are eaten by 62 species of birds, the most diligent canker-worm eater in towns being the English sparrow. Ground beetles and potter wasps are predaceous on the larvae, a mite devours the eggs and spiders prey upon the moths, eggs and larvae. The larvae are parasitized by Tachinid and Ichneumon flies, and the egg by a minute Platygaster fly. Hogs and chickens are sometimes efficient enemies.

Control Measures:

In orchards and woodlands spraying is the best method of control. A mixture of 1 1/4 pounds powdered arsenate of lead (or 2 1/2 pounds of the paste) in 50 gallons of water should be applied as soon as the leaves have opened in the Spring.

Trees in cities and in close proximity to buildings should be banded at the beginning of winter with tanglefoot applied to a collar of tarred paper, under which cotton has been pressed into the bark crevices. The tanglefoot should be kept sticky during warm spells in winter when the early evening temperature is above freezing, and especially during March, April and May until the larvae have left the trees to enter the ground. During the period when the great majority of the moths climb the trees (probably one or two weeks in March) they must be visited every day and the tanglefoot renewed as often as the surface is covered with moths. We have found a painter's gasoline blow-torch the most practical instrument for freeing the surface of the tanglefoot from moths.

Cultivation of the soil between July and November destroys the pupae of the Spring species and is an excellent control measure in orchards.

BIBLIOGRAPHY

Bailey, L. H. Notions about the Spraying of Trees; with Remarks on the Canker-worm. Cornell Bull. 101, 1895. pp. 480-502.

Beal, F. E. L. The Relations Between Birds and Insects. U. S. Dept. Agr., 1908. pp. 344-345.

Britton, W. E. Canker Worms. 8th Report State Entomologist of Conn. 1908. pp. 777-796.

Coquillett, D. W. Canker-worms. Circ. 9, 2nd Series, Div. of Ent., U. S. Dept. of Agr., 1895.

Dean, Geo. A. The Spring Canker-worm Situation in Kansas. Circ. 46, Kans. Agr. College, 1915.

Deane, Samuel. An Account of the Canker-worm. Newengland Farmer or Georgical Dictionary, Second Edition, 1797. (Extracts in Cornell Bull. 101)

Essig, E. O. Injurious and Beneficial Insects of California. Supplement to Monthly Bull., State Com. Hort., Vol. IV, No. 4, 1915, pp. 415-417.

Harris, T. W. Insects Injurious to Vegetation. Chap. V, pp. 460-472, 1852.

Howard, L. O. Progress in Economic Entomology in the United States. Yearbook, U. S. Dept. Agr. 1899, pp. 144-147.

Jennings, T. B. Climatological Data, Kansas Section. U. S. Weather Bureau. 1916-1917.

Kans. Ag. Exp. Sta. Reports, 1888 to 1914.

Kans. State Hort. Society Reports, 1873 to 1915.

Kellogg, V. L. Common Injurious Insects of Kansas, 1892. pp. 75-77.

Lodeman, E. G. The Spraying of Plants. pp. 61-64.

McIntosh, W. R. The Economic Value of Wild Birds. 2nd Bien. Report Com. of Hort. of Calif., 1907, p. 537.

Parrott, P. J. and Faville, E. E. The Spring Canker-worm. Bull. 77, Kans. Agr. Exp. Sta. 1898, pp. 31-36.

Peck, W. D. Natural History of the Canker-worm. (Extracts in Riley's 7th Mo; Report, pp. 89-90)

Quaintance, A. L. The Spring Canker-worm. Bull 68, part II, Bureau of Ent., 1907, pp. 17-22.

Riley, C. V. Canker Worms. 3rd Report U. S. Ent. Com. pp. 157-197.
The Canker-worm. 2nd Mo. Report, pp. 74-104.
The Canker-worm. 6th Mo. Report, pp. 24-30
Canker-worms. 7th Mo. Report, pp. 80-90.
Canker-worms. 8th Mo. Report, pp. 12-22.

Sanderson, E. D. Insect Pests of Farm, Garden and Orchard, 1912. pp. 570-575.

Saunders, Wm. Insects Injurious to Fruits. 1883, pp. 64-71.

Slingerland, M. V. and Crosby, C. R. Manual of Fruit Insects, 1914. pp. 77-89.

Smith, J. B. Economic Entomology. 2nd Revised Edition, 1906, pp. 307-308.

Wilson, H. F. and Lovett, A. L. The Canker Worm. (Notolopus sp.) Bien. Crop Pest and Hort. Report, 1911-12, Oregon Ag. Col. Exp. Sta. p. 155.

GENERAL INDEX