UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 805

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER December 15, 1919

# TWO LEAFHOPPERS INJURIOUS TO APPLE NURSERY STOCK

By

A. J. ACKERMAN, Scientific Assistant
Deciduous Fruit Insect Investigations

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## INTRODUCTION.

Serious injury to apple nursery stock due to the attack of leafhoppers attracted the writer's attention while engaged in the investigation of nursery fruit insects at West Chester, Pa. An examination of the injury showed the presence of two species of leafhoppers, the common apple leafhopper[1] and the rose leafhopper.[2] Further study proved that each species produced a distinct type of injury, that caused by the apple leafhopper being by far the more serious. The conflicting nature of the entomological literature regarding the character of injury caused by these two species and their habits led the writer, under the direction of Dr. A. L. Quaintance, of the Bureau of Entomology, to undertake a study of their individual life histories and the means for their control.

[1] *Empoasca mali* (Le Baron); order Hemiptera, suborder Homoptera, family Cicadellidae.
[2] *Empoa rosae* (Linn.); order Hemiptera, suborder Homoptera, family Cicadellidae.

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The destructiveness, habits, food plants, and life history of each species are treated separately herein. A detailed account of the experimental work carried out for the control of these two species together with the most efficient remedy is included.

The data on biology and control were obtained at West Chester, Pa., during the seasons of 1915 and 1916, supplemented by field observations at several points in southeastern Pennsylvania, and western Maryland.

## THE APPLE LEAFHOPPER, Empoasca mali (Le Baron).

### HISTORY.

This species was originally described by Le Baron (1) in 1853 [1] under the name *Tettigonia mali*, and it was recorded by him as injurious to fruit trees in Illinois. In 1862 the genus Empoasca was erected by Walsh (2) with a description of three new species, but no mention was made of *mali*. Carlos Berg (3, p. 273), in 1879, described a leafhopper from Argentina as *Typhlocyba phytophila*, and this name later was considered by Gillette to be a synonym of *Empoasca mali*. In 1883 Forbes (4) sent specimens of a green apple leafhopper to Uhler who determined them as belonging to the genus Empoa; subsequently these insects were described by Forbes (5) as a new species, *Empoa albopicta*. Woodworth (6) transferred *Empoa albopicta* Forbes to the genus Empoasca in 1889 and called it *Empoasca albopicta*. The first reference to this species under its correct name, *Empoasca mali*, was made by Gillette (7) in 1890. Osborn (8) and later Gibson (17) mentioned it as injurious to potatoes, and Gillette (9), in 1898, gave the food plants and distribution.

Frequent references to this insect have been made in American entomological literature under the name of "the apple leafhopper" and "the currant leafhopper," by Britton (12), Brues (13), and Garman (16) among others. It has been often referred to as the most injurious leafhopper, both to apple and to various field crops. Washburn (15), in 1908, was the first writer to treat of this insect at any length. He published a record of the seasonal history, food plants, injury, and control of the apple leafhopper as a nursery pest in Minnesota. In 1910 R. L. Webster (18) made a detailed study of the life history and control of this insect on apple nursery stock in Iowa. In 1915 Webster (20) published an account of *Empoasca mali*, treating it as a pest of potatoes.

### DISTRIBUTION.

There are no records showing that the apple leafhopper occurs in Europe. In America, outside of the United States, it has been reported from Okanagan, British Columbia, from Nova Scotia, several

[1] Figures in parentheses refer to "Literature cited," p. 34.

points in the Province of Ontario, from Mexico, Porto Rico, and Corrientes, Argentina. In the United States this species is widely disseminated, doubtless due to the variety and abundance of its host plants. From specimens in the collection of the United States National Museum, and from the collection, correspondence, and notes of the Bureau of Entomology, it appears to be present in almost every State in the Union. (See fig. 1.) It is found in greatest abundance throughout the eastern humid area of the Upper Austral Zone.

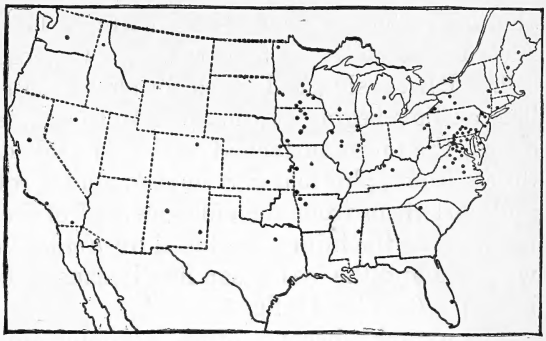


FIG. 1.—Distribution of the apple leafhopper (*Empoasca mali*) in the United States.

### FOOD PLANTS.

The food plants of *Empoasca mali* (Le B.) are very numerous and varied. In nurseries this insect prefers apple but it also feeds in great abundance on Norway maple and various oaks. Among field crops it is partial to alfalfa, clover, potato, and beets, in about the order named.

A list of all host plants reported, upon the majority of which the writer has noted this insect feeding, follows:

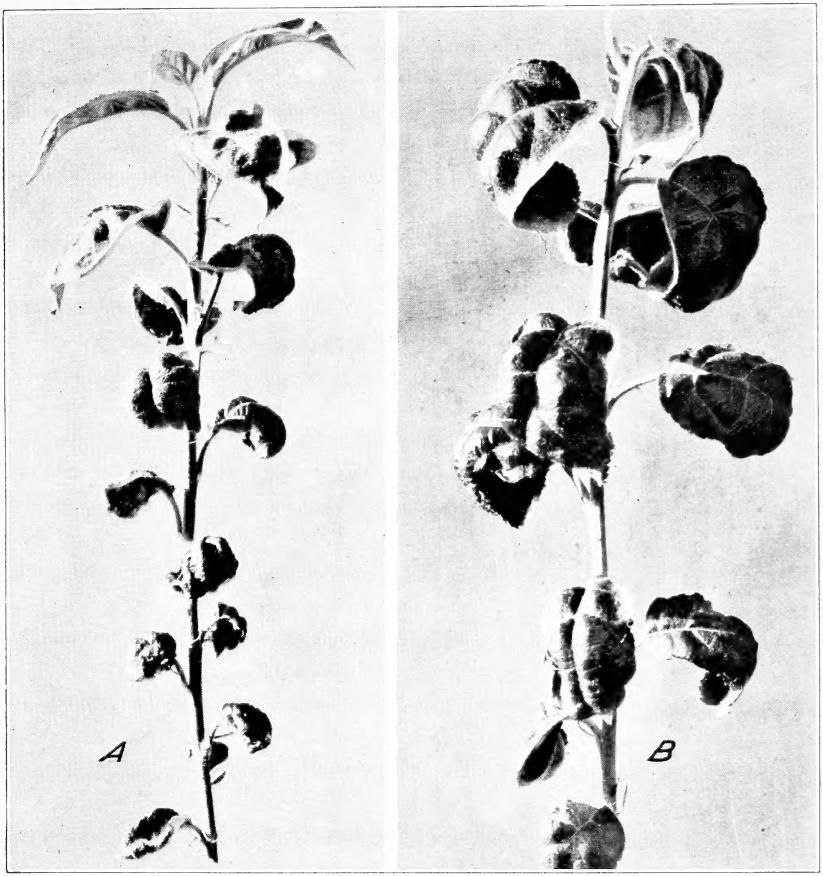
*Acer negundo*, box-elder.
*Acer platanoides*, Norway maple.
*Althea rosea*, hollyhock
*Amygdalus persica*, peach.
*Apium graveolens*, celery.
*Avena sativa*, oats.
*Beta vulgaris*, beets.
*Betula* sp., birch.
*Cannabis sativa*, hemp.
*Castanea* sp., chestnut.
*Corylus americana*, hazelnut.
*Crataegus* sp., hawthorn.
*Cydonia oblonga*, quince.
*Dahlia* sp., dahlia.
Gramineae, grasses.
*Hamamelis virginiana*, witch-hazel.
*Hicoria pecan*, pecan.
*Juglans nigra*, black walnut.
*Juglans* sp., walnut.
*Medicago sativa*, alfalfa.
*Phaseolus vulgaris*, beans.
*Populus* sp., poplar.
*Prunus virginiana*, choke-cherry.
*Prunus pissardi*, purple-leaved plum.
*Prunus* spp., cherries and plums.
*Pyrus baccata*, Siberian crab.
*Pyrus communis*, pear.
*Pyrus malus*, apple.
*Quercus* spp., oaks.
*Rheum rhaponticum*, rhubarb.
*Rhus cotinus*, smoke-tree.
*Ribes oxyacanthoides*, gooseberry.
*Ribes rubrum*, currant.
*Rubus* spp., blackberry and raspberry.
*Rosa* spp., roses.
*Secale cereale*, rye.
*Solanum tuberosum*, potato.
*Sorbus americana*, mountain ash.
*Sorghum* sp., sorghum.
*Syringa* sp., lilac.
*Tilia americana*, American linden.
*Trifolium* sp., clover.
*Ulmus americana*, American elm.
*Viburnum* sp., snowball.
*Vitis* spp., grapes.
*Zea* sp., corn.

### CHARACTER OF INJURY.

The injury caused by the apple leafhopper to nursery apple trees is due to the feeding of the nymphs and adults on the underside of the tender terminal leaves from which they extract the plant juices. As a result of this attack the leaves become undersized and curled (Pl. I, B), causing a decided check to the growth of the new wood. The curling begins at the apex and extends toward the base of the eaves, the lower surface always being rolled in. This type of injury differs from aphis leaf-curl in that aphids roll the leaves more tightly and curl them from the sides instead of from the tips. During the progress of the injury produced by *Empoasca mali* the leaves become wrinkled and the loss of sap finally causes the tips to dry up and turn brown. (See Pl. II, fig. 2.)

The nymphs, because of their greater numbers and due to the fact that they spend the entire nymphal period on a few leaves only, cause more serious injury than do the adults. The latter feed only for a short time, being principally engaged in egg-laying, and during this period they fly from one tree to another. Injury by the feeding of the adults, therefore, is of little importance when compared with the localized injury produced by the nymphs. Consequently, the stunted terminal growth is most apparent at the time when the nymphs are most abundant on the foliage. As the nymphs gradually disappear the terminal shoots seem to revive and develop normal leaves above the stunted ones. (See Pl. I, A.) At the time of infestation by the next brood of nymphs, however, a similar check to the new terminal growth is produced. Thus retardation in growth occurs periodically throughout the season corresponding to the periods of infestation by the successive nymphal broods, while intervening between each infestation there is a short period during which the terminals maintain a normal growth. Although the different broods of nymphs overlap slightly the successive checks in terminal growth usually are well defined.

In the vicinity of West Chester, Pa., there are three broods during the season and three corresponding checks in the terminal growth. The first growth-check takes place during the latter part of June when the first nymphal brood is feeding; a second and a third check appear during the latter part of July and August, respectively, at the time when the second and third broods of nymphs are most active on the foliage. The first brood is the most abundant on apple and consequently causes more injury than do either of the two following broods. Adults of the first brood do not confine their activities to apple alone, as many scatter to other host plants to feed and oviposit.




THE APPLE LEAFHOPPER (EMPOASCA MALI).

*A*, Terminal leaves of apple shoot outgrowing injury by the leafhopper; *B*, curled condition of terminal leaves caused by the leafhopper.

FIG. 1.—CAGES USED FOR REARING THE APPLE LEAFHOPPER IN NURSERY, WEST CHESTER, PA.

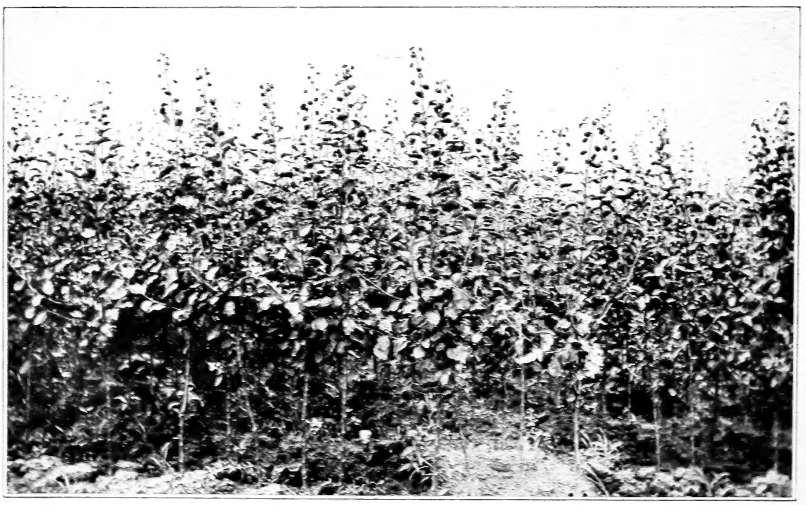
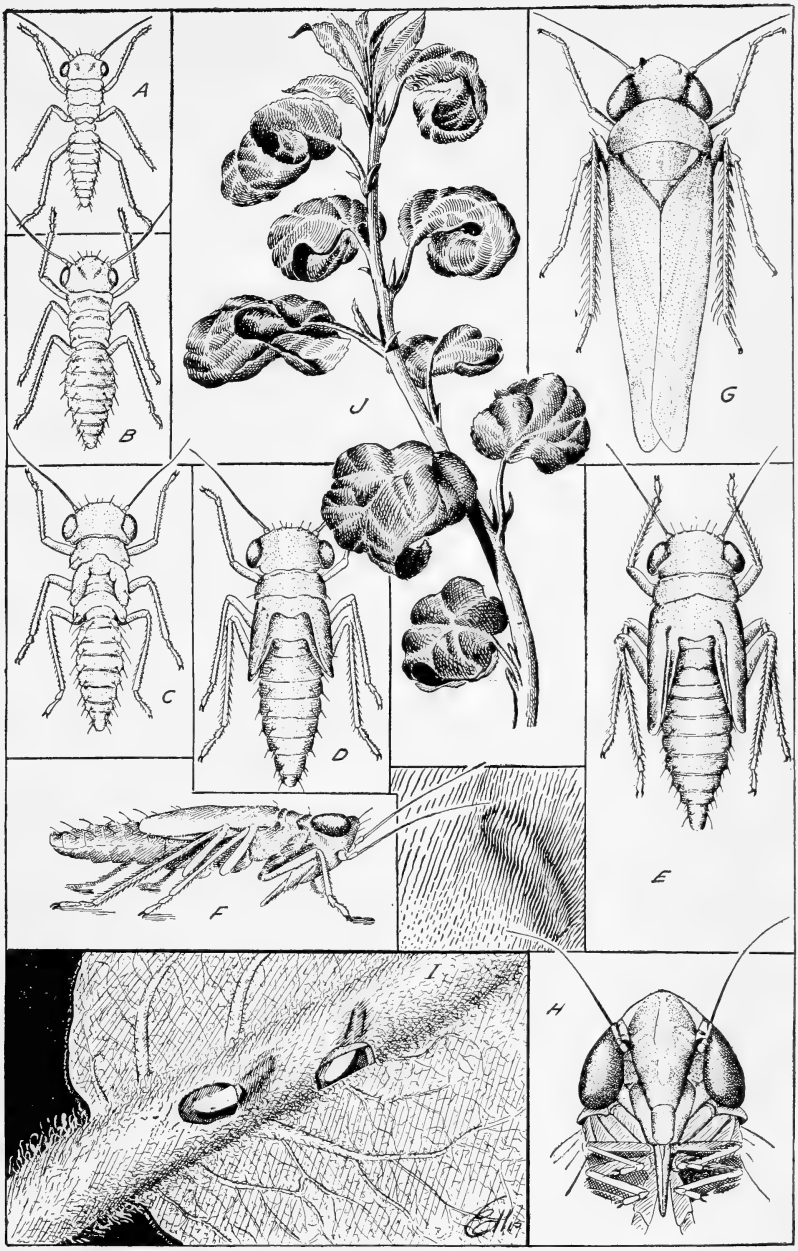


FIG. 2.—TERMINAL LEAVES OF NURSERY APPLE TREES CURLED BY THE APPLE LEAFHOPPER.




## THE APPLE LEAFHOPPER.

*A*, First nymphal stage; *B*, second stage; *C*, third stage; *D*, fourth stage; *E*, fifth stage; *F*, side view of fifth stage; *G*, adult; *H*, front view of head of adult; *I*, eggs in tissue on underside of apple leaf; *J*, curled condition of terminal leaves due to attack by the apple leafhopper on apple.

As a result of the continued checking of the growth, due to the infestation of the apple leafhopper, nursery apple trees often require an additional year's growth before they become of marketable size.

### EXTENT OF INJURY AND INFLUENCING FACTORS.

The extent of injury varies according to the age of the nursery stock and according to the differences in the character of growth of apple varieties.

Seedlings and the initial growth of buds and grafts are very seriously injured. Nursery stock at this stage is in its most critical period of growth and is injured very easily. Furthermore, any injury at this stage is not readily outgrown.

After the first year's growth the more vigorous varieties become partially immune to serious injury and succeed in maintaining a satisfactory growth, while slow-growing and tender-leaved varieties are at all times badly injured by the attack of this insect. This is easily understood since, even under normal conditions, the latter make but a very ordinary growth and are entirely unable to withstand a serious check. Among the varieties most severely injured in Pennsylvania nurseries Red Astrachan, a particularly slow grower during the first two seasons, ranks first, followed by Smith's Cider, Starr, Early Harvest, Summer Rambo, Delaware Winter, Wagoner, Golden Russet, Early Ripe, Wealthy, and Alexander.

### DESCRIPTION OF STAGES.

#### Egg.

Pl. III, I.

The egg is elongate, subcylindrical in form, very delicate, slightly curved from end to end, somewhat rounded at both ends but more so at the anterior one. When first deposited it is rather transparent but in a few days it changes to a pale yellow color, while a small white cap forms at the anterior end through which the red eyes of the immature nymph are perceptible.

Average length of 15 eggs 0.82 mm., width 0.25 mm.

#### Nymph.

Pl. III, A–F.

*First instar.*—Color pale white, changing to a light yellowish green after feeding. Eyes dull red. Small pale spines on the dorsal side of the head, thorax, and abdomen; the latter with four spines to each segment arranged in two longitudinal rows along each side, one spine situated dorso,laterally, the other ventro-laterally. Posterior margin of metathorax blunt. First two segments of antennæ pale, the remainder dusky. Average length of 16 specimens 1 mm.

*Second instar.*—General color light yellowish green. Eyes lose some of their red color. Posterior border of metathorax sharp in outline. First two segments of antennæ light yellow, remainder dusky. Average length of 16 specimens 1.30 mm.

*Third instar.*—General color pale yellowish green. Eyes almost pearl white. Body more robust than in first two stages. Wing pads appear as lateral buds extending

to the hind margin of the first abdominal segment. Spines darker and more prominent. Average length of 16 specimens 1.85 mm.

*Fourth instar.*—Head and thorax yellowish green; abdomen yellow in color. Eyes pearl white. Wing pads extend to hind margin of second abdominal segment. Spines prominent. Average length of 16 specimens 2.1 mm.

*Fifth instar.*—Head and thorax pale green; abdomen yellow. Eyes dull white. Wing pads extend to or nearly to the hind margin of the fourth abdominal segment. First two antennal segments green, remainder dusky. Body broader than in previous stage. Average length of 16 specimens 2.6 mm.

ADULT.

Pl. III, G, H.

General color of adult pale green; face with a white median longitudinal line in older specimens but composed of a series of white spots in newly hatched individuals; median line extending from a point midway between the ocelli to a point half the distance to lower margin of clypeus; two short white diagonal bands on each side of median line, the lower one the smaller; a short white line, often merely two spots, beyond the diagonal and just above the antenna; a faint white line midway between the ocellus and eye; antennæ 1 mm. in length, arising near the lower frontal border of the eyes; clypeus one-third longer than broad; loræ narrow, not reaching the tips of clypeus, concave below eyes; genæ almost as long and half as broad as clypeus, with one or two faint white spots. Vertex dark green with a median white line, narrowest in middle, its length equal to distance between the ocelli; a white band on each side, dorso-lateral and diagonal to median line. Two ocelli present, marked by two white spots and situated on frontal margin of vertex, their distance apart equal to twice that from the eye to the ocellus; eyes dull white, reddish brown after death. Pronotum pale green, hind margin very pale, with eight white spots along the frontal margin, the last spot at each end small and often fused with the one next to it so as to form only six spots; mesonotum with two parallel white longitudinal lines centrally located and connected by a traverse one in the form of a letter H, a faint white diagonal line present on each lateral margin; scutellum small with a large white triangular area in the center and a small spot on each side along the frontal margin. Abdominal segments yellowish green with transverse yellow stripes on their hind margins, anal segment dark green. Wings semitransparent, pale yellowish green. Legs green, tarsi dusky at the tips. Sexual appendages ciliated in both sexes. Average length of 16 specimens 3.12 mm.

### ALLIED SPECIES.

Three other species of Empoasca were found associated with *E. mali* on the foliage of nursery apple trees at West Chester, Pa. These species were determined by the late Otto Heidemann, of the Bureau of Entomology, as follows: *E. birdii* Goding, *E. flavescens* (Fabricius), and *E. unicolor* Gillette. *Birdii* and *flavescens* are very closely allied species, the former being considered by Gillette to be merely a color variety of the latter; these two species resemble *mali* quite closely and they may be easily mistaken for it. *Unicolor*, on the other hand, differs markedly from any of the above three and is readily distinguished from them.

*Birdii* differs from *mali* by its smaller size and paler color, by the presence of smoky markings on the elytra, and by the three white spots on the pronotum.

No attempt was made to study the life history and habits of *birdii* but they are probably much the same as those of *mali*. From

field observations it was found that this species hibernates in the adult stage in woodlands near the nursery at West Chester. The adults become active in the spring about a week earlier than *mali*, confining their feeding at first to the foliage of skunk cabbage. From this plant they scatter to grasses and weeds beneath the apple trees in the nursery a few days prior to the first appearance of *mali*. During the early spring they prefer to feed on any low green vegetation in the nursery row, and never become abundant on the foliage of apple until about mid-season. At this time they appear in numbers associated with *mali* on the terminal leaves. The extent of damage caused by *birdii* is small compared with that caused by the common apple leafhopper, and for this reason little attention has been paid to it heretofore.

*Flavescens* differs from *birdii* by the absence of the characteristic white markings of the pronotum and the smoky bands crossing the elytra.

This species is allied very closely to *birdii* in appearance, and probably in habits and life history, but it is less abundant on the apple.

*Unicolor* is readily separated from *mali* by the absence of the conspicuous white markings of the face and the notum, by its greater length and robustness, and by the presence of a pale white spot on the middle of the anterior margin of the pronotum and a blue blotch on the scutellum.

Few field observersations were obtained in regard to the habits of *unicolor*. The nymphs of the first brood were found on apple at approximately the same date and about as abundantly as those of *mali* at Hagerstown, Md. The adults of this species do not confine their attack to the terminal leaves, being found more frequently on the lower part of the trees. This species was taken in scant numbers on apple in the vicinity of West Chester and the injury caused by it was negligible.

## LIFE HISTORY AND HABITS.

### Methods of Study.

In studying the life history of the two species of apple leafhoppers concerned in this bulletin all data were obtained under outdoor conditions by rearing the insects on young apple stock in the nursery row. Seedlings were planted out early in the spring of 1915 and again in 1916 on a plot of ground at one end of a few nursery rows.

Riley cages and arc-light globe cages (Pl. II, A) were used for obtaining records of the length of the egg stage, the extent of reproduction per female, and the longevity of adults of the different broods. The globe cages were well shaded from the sun by means of large muslin covers over their tops, while ventilation was obtained both from above and below. With the use of such cages practically normal conditions were secured for the rearing of the leafhopper

material. The plants were encaged before the hibernating adults made their appearance in the nursery, thereby preventing outside infestation.

Special cages were constructed for experiments in determining the length of the nymphal stages. Various types of cages were tried in an effort to secure one in which the nymph could be reared under as nearly normal conditions as possible.

The type of cage finally decided upon was made as follows: A piece of thin sheet-cork was cut about 2 inches square, in the center of which a 1-inch square hole was made. White muslin cloth was stretched tightly over one side of the cork and glued fast so as to cover the center hole. Heavy wadding cut to the shape of the cork, but leaving the center open, was glued to the other side. With the muslin side out, the cage was then placed over a newly hatched nymph on the lower surface of a leaf. A square of stiff cardboard of the same size as the cork was placed on the upper side of the leaf, and the cardboard, leaf, and cage were fastened together by paper clips. The young nymph within the cage received ventilation from both sides, through the porous wadding and through the muslin top. The leaf tissue was protected against injury by the cardboard on its upper surface and by the wadding on its lower surface. The nymph was examined daily by removing the paper clips and lifting the cage slightly; in this manner a record of the molts was obtained.

Although this cage was a little heavy when used on the small leaves of seedlings, it proved satisfactory when fastened to the larger leaves of two-year trees. For this reason the nymphal stages were obtained by transferring newly hatched nymphs from globe cages to the cork cages on uninfested leaves of older trees in the nursery row.

### Number of Generations.

There are three generations of the apple leafhopper at West Chester, Pa. These generations overlap slightly but they are easily distinguished by the resultant injury caused by each. The first generation, covering the period from the time of egg deposition by the overwintered females to the death of the first-brood adults, extends from the last week in May to the first week in August. The second generation covers the period from the first week in July until the latter part of September. The third generation, including the hibernating adults, lasts from the first week in September until the early part of July of the following season. Adults of this generation hatch during the first week in September and remain on the trees until late in November when they seek shelter for the winter. In the spring of the following year overwintered adults are found on the trees from the last week in May until death, which occurs during June and early July.

Forbes and Hart (10) in 1900 mentioned the occurrence of four or more generations in Illinois. In 1908 Washburn (15) suggested that there were two and possibly three generations in Minnesota. R. L. Webster (18) in 1910 recorded four generations at Ames, Iowa. E. H. Gibson, of the Bureau of Entomology, has noted as many as five generations in southern Missouri, and six in southern Mississippi.

### The Egg.

The eggs are laid singly in the sides of the mid-vein and occasionally in the smaller veins of the terminal leaves. They are deposited in pockets just under the epidermis, usually lying in a longitudinal position. It is very difficult to locate the eggs as they are the same color as the tissue in which they are embedded, while the epidermis under which they are hidden is covered by the pubescence of the leaf. When the pubescence is removed, the tissue covering the egg appears slightly distorted and eventually becomes discolored. In making dissections of the leaf tissue the delicate egg is often crushed, whereupon the egg contents may be mistaken for the plant juice in the vein. When ready to hatch, the immature nymph pushes its head through the anterior end of the eggshell and forces a tiny hole in the thin epidermal leaf-covering, slowly drawing its body free from the enveloping tissue.

Eggs of *Empoasca mali* have been found in the leaves of the following host plants: Apple, pear, peach, plum, cherry, quince, alfalfa, beet, and potato.

Adults of all three generations deposit summer eggs in leaves in the manner mentioned above. Washburn (15) stated in 1908 that the last-brood adults of this species deposit winter eggs under the bark of nursery apple trees in Minnesota, and that the nymphs hatching therefrom the following spring attack the lower leaves of the trees. Webster (18) in 1910 made similar observations in Iowa. At West Chester, Pa., the apple leafhopper certainly does not pass the winter in the egg stage. Several experiments were made in the attempt to obtain winter eggs by confining numerous pairs of third-brood adults in cages, but all proved unsuccessful. Field observations for two seasons on several thousand trees also substantiate the above view. However, winter eggs of the rose leafhopper (which will be treated later) were found in abundance in this locality, the nymphs of which confine their feeding to the lower leaves of the trees.

### The Nymph.

The newly-hatched nymphs are very small, wingless, white in color, and of the same form as the adults. Immediately after hatching they settle down to feed, inserting their minute beaks in the leaf tissue and sucking the plant juices. A day or two after taking food into

their bodies the young nymphs change to a pale green color, which is the characteristic color during the remainder of their nymphal life. The nymphs pass through five stages of development before they reach maturity, molting and increasing in size at the completion of each stage. The nymphs are very agile in their movements and run in a zig-zag or sidling manner; only fourth and fifth stage nymphs are able to hop.

The first nymphs of the season appear on the trees about June 1, and the nymphal infestation is at its height about three weeks later.

### The Adult.

The adults are very active, especially on warm, sunny days, when they rise from the trees in swarms at the least disturbance. During flight the hoppers seldom rise over the tops of the trees but fly sidewise to the next nursery row.

Records have appeared stating that this insect is strongly attracted to artificial light, but this view is contrary to observations made by the writer. Among the leafhoppers found swarming around electric lights the two allied species *E. flavescens* and *E. birdii* were far more abundant than this species.

The overwintered adult leafhoppers become active during the warm days about the middle of May. Upon leaving their hibernating places they immediately disperse to apple blocks in the nursery. The first adults of the season appearing on apple stock in the nursery were found on May 18; by June 1 they become quite abundant on the foliage in this section. For several days they confine their activities to feeding on the underside of the terminal leaves. After feeding for about a week the adults mate and soon begin depositing the first-brood eggs.

Adults of all three generations have the same habits on apple. Third-brood adults feed on apple foliage in the fall until cold weather sets in. Prior to going into hibernation they collect on the lower leaves of the trees and on several varieties of low-growing weeds in the nursery row, being especially abundant on sorrel (*Rumex* sp.).

### Longevity of Overwintered Adults.

Data on the length of life of the adult apple leafhoppers were obtained with great difficulty, due to their activity. A Riley cage was used in this experiment in which 50 adults were confined on a young apple tree. The newly transforming nymphs were removed from the foliage from time to time to prevent confusing them with the adults. During the progress of the examinations a few adults made their escape. A record of the date on which the adults died is given in Table I. It will be noted that death occurred in most cases by July 1. From observations in the field it was found that practically

all overwintered adults had disappeared from the trees by the first week in July.

TABLE I.—*Longevity of overwintered adult apple leafhoppers; 50 adults placed in cage June 8, 1915.*

| Date of examination. | Number dead. | Date of examination. | Number dead. |
|---|---|---|---|
| June 20 | 4 | June 30 | 1 |
| June 21 | 1 | Do | [1]1 |
| June 22 | 6 | July 1 | 1 |
| Do | [1]1 | July 3 | 1 |
| June 23 | 2 | July 12 | 1 |
| June 24 | 4 | July 13 | 2 |
| June 25 | 5 | July 14 | 1 |
| June 26 | 1 | July 15 | 2 |
| June 27 | 3 | July 16 | 1 |
| Do | [1]1 | July 17 | 1 |
| June 28 | 2 | July 18 | 1 |
| June 29 | 2 | July 19 | 2 |

[1] Escaped.

EXTENT OF REPRODUCTION BY OVERWINTERED FEMALES.

Pairs of overwintered adults were placed on young trees in globe cages to determine the number of eggs deposited by a female in confinement. The adult leafhoppers were allowed to remain on the foliage until they died. Examinations were made from time to time and a record was kept of the number of nymphs removed at each examination. This method of obtaining the extent of reproduction does not take into consideration the number of eggs that failed to hatch; however, it shows approximately the number of eggs deposited by a single female.

Two experiments were carried out and averages of 27 and 28 eggs per female hatched in the respective cages. In Table II the number of nymphs removed is given.

TABLE II.—*Number of first-brood nymphs produced by overwintered adult apple leafhoppers in confinement, West Chester, Pa., 1915.*

CAGE NO. 1.—TWO PAIRS OF OVERWINTERED ADULTS PLACED IN CAGE ON YOUNG APPLE TREE JUNE 9, 1915.

| Date of examination. | Number of first-brood nymphs removed. | Date of examination. | Number of first-brood nymphs removed. |
|---|---|---|---|
| June 24 | 43 | July 7 | 2 |
| June 26 | 2 | July 30 | 0 |
| June 29 | 6 | | |
| July 1 | 1 | Average | 27 |

CAGE NO. 2.—THREE PAIRS OF OVERWINTERED ADULTS PLACED IN CAGE ON YOUNG APPLE TREE JUNE 7, 1915.

| | | | |
|---|---|---|---|
| June 24 | 31 | July 7 | 10 |
| June 26 | 14 | July 10 | 1 |
| June 29 | 15 | July 20 | 3 |
| June 30 | 4 | July 30 | 0 |
| July 1 | 1 | | |
| July 3 | 5 | Average | 28 |

### First Generation.

#### FIRST BROOD OF EGGS.

*Length of incubation period.*—The adult females are very rarely seen depositing eggs since they are very agile in their movements and take flight at the slightest disturbance. Moreover, even though a female is observed in the act of oviposition, the egg is seldom detected, as it is inserted under the epidermis and is further hidden by the downy pubescence of the leaf. For these reasons only approximate records of the length of the egg stage could be secured.

Data on the incubation period were obtained by confining copulating pairs of overwintered adults on a seedling tree in a globe cage. The adults were removed after 24 hours and a daily record was kept of the nymphs as they hatched. The length of the egg stage, together with the average mean temperature for the entire period, is given in Table III. The average incubation period was 7.5 to 9.5 days; the maximum, 10 to 12 days; the minimum, 5 to 7 days.

TABLE III.—*Length of incubation period of first-brood eggs deposited by overwintered females of the apple leafhopper in confinement, West Chester, Pa., 1915.*

TWENTY PAIRS OF OVERWINTERED ADULTS PLACED ON APPLE TREE JUNE 13, 1915, 12 M.; ADULTS REMOVED JUNE 14, 12 M.

| Date of removal of newly hatched nymphs. | Number of nymphs removed. | Length of incubation period. | Average temperature for entire period. |
|---|---|---|---|
| 1915. | | *Days.* | °*F.* |
| June 20, 12 m | 2 | 5 – 7 | 79.56 |
| June 21, 12 m | 47 | 6 – 8 | 78.61 |
| June 22, 12 m | 30 | 7 – 9 | 77.00 |
| June 23, 12 m | 10 | 8 –10 | 75.90 |
| June 24, 12 m | 4 | 9 –11 | 75.20 |
| June 25, 12 m | 1 | 10 –12 | 75.07 |
| Average | | 7.5– 9.5 | 76.89 |

#### FIRST BROOD OF NYMPHS.

*Length of stages.*—The length of the nymphal stages and of the entire nymphal period was obtained by confining newly hatched nymphs in the cork cages described on page 8. Each cage was examined daily and a record made of the length of each stage, the cast skins being removed from the cages after each molt. The length of each stage and of the entire nymphal period is shown in Table IV; the average mean temperature for each nymphal period is also included. The average length of the nymphal period for 22 nymphs was 18.7 days; the maximum, 22 days; the minimum, 15 days.

TABLE IV.—*Length of nymphal stages of the first brood of the apple leafhopper at West Chester, Pa., 1915.*

First brood, June and July.

| Date of hatching. | First molt. | First stage. | Second molt. | Second stage. | Third molt. | Third stage. | Fourth molt. | Fourth stage. | Fifth molt. | Fifth stage. | Total nymphal period. | Average mean temperature for nymphal period. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1915. | 1915. | *Days.* | 1915. | *Days.* | 1915. | *Days.* | 1915. | *Days.* | 1915. | *Days.* | *Days.* | °*F.* |
| June 12 | June 15 | 3 | June 17 | 2 | June 21 | 4 | June 25 | 4 | June 30 | 5 | 18 | 75.18 |
| Do | June 16 | 4 | June 18 | 2 | ...do | 3 | June 26 | 5 | July 1 | 5 | 19 | 75.47 |
| Do | June 18 | 6 | June 21 | 3 | June 25 | 4 | June 29 | 4 | July 3 | 4 | 21 | 75.79 |
| Do | June 16 | 4 | June 19 | 3 | June 22 | 3 | June 27 | 5 | July 1 | 4 | 19 | 75.47 |
| June 13 | ...do | 3 | June 20 | 4 | June 24 | 4 | ...do | 3 | July 2 | 5 | 19 | 75.20 |
| Do | June 17 | 4 | ...do | 3 | June 21 | 1 | June 26 | 5 | July 1 | 5 | 18 | 75.15 |
| Do | June 18 | 5 | ...do | 2 | ...do | 1 | June 27 | 6 | July 4 | 7 | 21 | 75.70 |
| Do | June 16 | 3 | ...do | 4 | June 25 | 5 | June 29 | 4 | July 3 | 4 | 20 | 75.52 |
| Do | June 18 | 5 | ...do | 2 | June 23 | 3 | June 27 | 4 | July 2 | 5 | 19 | 75.20 |
| June 14 | June 16 | 2 | June 19 | 3 | June 21 | 2 | June 29 | 8 | July 3 | 4 | 19 | 75.20 |
| Do | June 17 | 3 | June 20 | 3 | June 24 | 4 | June 28 | 4 | July 2 | 4 | 18 | 74.84 |
| Do | June 18 | 4 | ...do | 2 | June 23 | 3 | ...do | 5 | July 3 | 5 | 19 | 75.20 |
| Do | ...do | 4 | June 21 | 3 | June 29 | 8 | July 2 | 3 | July 6 | 4 | 22 | 75.28 |
| Do | June 17 | 3 | ...do | 4 | June 23 | 2 | June 26 | 3 | July 1 | 5 | 17 | 74.77 |
| June 15 | June 18 | 3 | ...do | 3 | June 24 | 3 | June 28 | 4 | July 3 | 5 | 18 | 74.81 |
| Do | ...do | 3 | ...do | 3 | June 25 | 4 | June 29 | 4 | July 4 | 5 | 19 | 75.05 |
| Do | June 19 | 4 | ...do | 2 | June 24 | 3 | June 28 | 4 | July 1 | 3 | 16 | 74.32 |
| Do | ...do | 4 | June 22 | 3 | June 27 | 5 | July 1 | 4 | July 6 | 5 | 21 | 74.95 |
| June 18 | June 21 | 3 | June 26 | 5 | June 29 | 3 | July 3 | 4 | ...do | 3 | 18 | 74.36 |
| Do | June 20 | 2 | June 24 | 4 | ...do | 5 | July 2 | 3 | ...do | 4 | 18 | 74.36 |
| June 19 | June 21 | 2 | ...do | 3 | June 26 | 2 | June 29 | 3 | July 4 | 5 | 15 | 74.06 |
| June 23 | June 26 | 3 | June 30 | 4 | July 4 | 4 | July 8 | 4 | July 11 | 3 | 18 | 75.07 |
| Average | ..... | 3.5 | ..... | 3 | ..... | 3.4 | ..... | 4.2 | ..... | 4.5 | 18.7 | 75.04 |

FIRST BROOD OF ADULTS.

*Longevity.*—First-brood adults were confined in a Riley cage to determine the length of life. Most of the hoppers died by August 1, as shown in Table V.

TABLE V.—*Longevity of first-brood adult apple leafhoppers; 50 adults placed in cage July 2, 1915.*

| Date of examination. | Number dead. | Date of examination. | Number dead. |
|---|---|---|---|
| July 7 | 6 | July 24 | [1] 2 |
| July 8 | 3 | July 26 | 2 |
| July 9 | 6 | July 27 | 3 |
| July 10 | 1 | July 30 | 4 |
| Do | [1] 2 | July 31 | 1 |
| July 11 | 2 | Aug. 2 | 3 |
| July 12 | 1 | Aug. 4 | 2 |
| July 13 | 3 | Aug. 5 | 1 |
| July 17 | 5 | Do | 1 |
| July 24 | 1 | Aug. 6 | 1 |

[1] Escaped.

*Extent of reproduction.*—Two globe cage experiments were made to determine the extent of reproduction by a first-brood female in confinement. In one cage two pairs of adults, in the other three pairs were confined until death occurred. The average number of eggs

deposited per female in cage 1 was approximately 24; in cage 2, approximately 22. (See Table VI.)

TABLE VI.—*Number of second-brood nymphs produced by first-brood adult apple leafhoppers in confinement, West Chester, Pa., 1915.*

CAGE NO. 1.—TWO PAIRS OF FIRST-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE JUNE 30, 1915.

| Date of examination. | Number of second-brood nymphs removed. | Date of examination. | Number of second-brood nymphs removed. |
|---|---|---|---|
| July 13 | 14 | July 27 | 1 |
| July 17 | 1 | July 30 | 1 |
| July 20 | 22 | Aug. 10 | 0 |
| July 22 | 8 | | |
| July 24 | 1 | Average | 24 |

CAGE NO. 2.—THREE PAIRS OF FIRST-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE JUNE 30, 1915.

| | | | |
|---|---|---|---|
| July 14 | 6 | July 29 | 11 |
| July 17 | 3 | July 30 | 3 |
| July 20 | 17 | Aug. 10 | 0 |
| July 22 | 6 | | |
| July 24 | 5 | Average | 22 |
| July 27 | 15 | | |

## SECOND GENERATION.

### SECOND BROOD OF EGGS.

*Length of incubation period.*—As will be noted in Table VII, the length of the egg stage of this brood is somewhat shorter than that of the first brood. This fact undoubtedly is due to the higher temperatures occurring throughout the incubation period of the second-brood eggs. As in Table III only an approximation of the length of the incubation period was obtained. The average incubation period of second-brood eggs was 6 to 8 days; the maximum, 9 to 11 days; the minimum, 3 to 5 days.

TABLE VII.—*Length of incubation period of second-brood eggs of the apple leafhopper, West Chester, Pa., 1915.*

TWENTY-FIVE PAIRS OF FIRST-BROOD ADULTS PLACED ON APPLE TREE JULY 7, 1915, 3 P. M.; ADULTS REMOVED JULY 8, 3 P. M.

| Date of removal of newly hatched nymphs. | Number of nymphs removed. | Length of incubation period. | Average temperature for entire period. |
|---|---|---|---|
| 1915. | | *Days.* | °*F.* |
| July 12, 3 p. m. | 9 | 3–5 | 77.08 |
| July 13, 3 p. m. | 8 | 4–6 | 77.42 |
| July 14, 3 p. m. | 6 | 5–7 | 77.50 |
| July 15, 3 p. m. | 15 | 6–8 | 77.66 |
| July 16, 3 p. m. | 13 | 7–9 | 78.05 |
| July 17, 3 p. m. | 12 | 8–10 | 78.86 |
| July 18, 3 p. m. | 1 | 9–11 | 79.54 |
| Average | | 6–8 | 78.01 |

SECOND BROOD OF NYMPHS.

*Length of stages.*—The length of the stages and of the entire nymphal period of this brood was slightly shorter than in the case of first-brood nymphs. Table VIII shows that the average nymphal period of second-brood nymphs was 15.8 days; the maximum, 17 days; the minimum, 15 days.

TABLE VIII.—*Length of nymphal stages of the second brood of the apple leafhopper at West Chester, Pa., 1915.*

SECOND BROOD, JULY AND AUGUST.

| Date of hatching. | First molt. | First stage. | Second molt. | Second stage. | Third molt. | Third stage. | Fourth molt. | Fourth stage. | Fifth molt. | Fifth stage. | Total nymphal period. | Average mean temperature for nymphal period. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1915. | 1915. | *Days.* | 1915. | *Days.* | 1915. | *Days.* | 1915. | *Days.* | 1915. | *Days.* | *Days.* | °*F.* |
| July 14 | July 17 | 3 | July 19 | 2 | July 22 | 3 | July 25 | 3 | July 30 | 5 | 16 | 79.70 |
| July 17 | July 19 | 2 | July 23 | 4 | July 26 | 3 | July 30 | 4 | Aug. 3 | 4 | 17 | 80.22 |
| Do | July 20 | 3 | July 22 | 2 | July 24 | 2 | July 28 | 4 | Aug. 1 | 4 | 15 | 80.50 |
| July 20 | July 22 | 2 | July 23 | 1 | July 27 | 4 | July 30 | 3 | Aug. 5 | 6 | 16 | 79.05 |
| Do | do | 2 | July 25 | 3 | July 28 | 3 | do | 2 | Aug. 4 | 5 | 15 | 79.00 |
| Do | do | 2 | do | 3 | July 29 | 4 | Aug. 1 | 3 | Aug. 5 | 4 | 16 | 79.05 |
| July 21 | July 24 | 3 | July 28 | 4 | July 31 | 3 | Aug. 3 | 3 | Aug. 7 | 4 | 17 | 78.27 |
| July 22 | July 25 | 3 | July 29 | 4 | do | 2 | Aug. 2 | 2 | Aug. 6 | 4 | 15 | 79.40 |
| July 23 | do | 2 | do | 4 | July 30 | 1 | do | 3 | Aug. 7 | 5 | 15 | 78.56 |
| Do | July 26 | 3 | do | 3 | do | 1 | Aug. 3 | 4 | Aug. 8 | 5 | 16 | 78.52 |
| Do | July 25 | 2 | July 28 | 3 | do | 2 | Aug. 2 | 3 | Aug. 7 | 5 | 15 | 78.56 |
| Do | July 26 | 3 | do | 2 | do | 2 | Aug. 3 | 4 | Aug. 8 | 5 | 16 | 78.52 |
| Do | do | 3 | July 27 | 1 | do | 3 | do | 4 | do | 5 | 16 | 78.52 |
| Do | July 27 | 4 | July 29 | 2 | Aug. 1 | 3 | Aug. 5 | 4 | Aug. 9 | 4 | 17 | 78.38 |
| Average | | 2.6 | | 2.7 | | 2.5 | | 3.2 | | 4.6 | 15.8 | 79.01 |

SECOND BROOD OF ADULTS.

*Longevity.*—In Table IX the date of death for 40 second-brood adults is recorded.

TABLE IX.—*Longevity of second-brood adults; 40 adults placed in cage Aug. 13, 1915.*

| Date of examination. | Number dead. | Date of examination. | Number dead. |
|---|---|---|---|
| Aug. 17 | 4 | Sept. 16 | 1 |
| Aug. 23 | 2 | Sept. 20 | 2 |
| Aug. 26 | 10 | Sept. 24 | 2 |
| Sept. 1 | 4 | Sept. 27 | 3 |
| Do | [1] 3 | Sept. 30 | 2 |
| Sept. 13 | 5 | Do | [1] 1 |
| Do | [1] 1 | | |

[1] Escaped.

*Extent of reproduction.*—Four separate experiments were made to determine the number of eggs deposited by a female of the second brood. Two, three, four, and five pairs of adults, respectively, were

placed in separate cages and a record of the number of eggs hatched was kept. The average number of eggs deposited per female was 19.5 in cage 1, 21 in cage 2, 20.2 in cage 3, and 18.4 in cage 4. The total average for the four cages was 19.8 eggs per female. (See Table X.)

TABLE X.—*Number of third-brood nymphs produced by second-brood adult apple leaf-hoppers in confinement.*

CAGE NO. 1.—TWO PAIRS SECOND-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE AUG. 5, 1915.

| Date of examination. | Number of third-brood nymphs removed. | Date of examination. | Number of third-brood nymphs removed. |
|---|---|---|---|
| Aug. 16 | 21 | Sept. 7 | 0 |
| Aug. 23 | 12 | | |
| Aug. 30 | 6 | Average per female | 19.5 |

CAGE NO. 2.—THREE PAIRS SECOND-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE AUG. 5, 1915.

| | | | |
|---|---|---|---|
| Aug. 16 | 12 | Sept. 14 | 3 |
| Aug. 23 | 29 | Sept. 28 | 0 |
| Aug. 31 | 14 | | |
| Sept. 4 | 5 | Average per female | 21 |

CAGE NO. 3.—FOUR PAIRS SECOND-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE AUG. 5, 1915.

| | | | |
|---|---|---|---|
| Aug. 16 | 37 | Sept. 14 | 5 |
| Aug. 23 | 24 | Sept. 28 | 0 |
| Aug. 31 | 8 | | |
| Sept. 4 | 7 | Average per female | 20.2 |

CAGE NO. 4.—FIVE PAIRS SECOND-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE AUG. 9, 1915.

| | | | |
|---|---|---|---|
| Aug. 23 | 34 | Sept. 22 | 1 |
| Aug. 31 | 18 | Sept. 30 | 0 |
| Sept. 4 | 25 | | |
| Sept. 14 | 14 | Average per female | 18.4 |

## THIRD GENERATION.

### THIRD BROOD OF EGGS.

*Length of incubation period.*—Three separate cages were used in the experiments on the length of the incubation period of third-brood eggs. The average incubation period was 9.6 to 10.3 days for cage 1; 9.5 to 11.5 days for cage 2; and 10 to 12 days for cage 3. (See Table XI.)

TABLE XI.—*Length of incubation period of third-brood eggs of the apple leafhopper, West Chester, Pa., 1915.*

CAGE NO. 1.—SIX PAIRS OF ADULTS PLACED ON APPLE TREE AUG. 6, 1915, 8 A. M.; ADULTS REMOVED AUG. 6, 4 P. M.

| Date of removal of newly hatched nymphs. | Number of nymphs removed. | Incubation period. | Average temperature for entire period. |
|---|---|---|---|
| 1915. | | *Days.* | °F |
| Aug. 15, 4 p. m. | 12 | 8.6–9.3 | 75.95 |
| Aug. 16, 4 p. m. | 2 | 9.6–10.3 | 76.40 |
| Aug. 17, 4 p. m. | 2 | 10.6–11.3 | 76.00 |
| Average | | 9.6–10.3 | 76.11 |

CAGE NO. 2.—TEN PAIRS OF ADULTS PLACED ON APPLE TREE AUG. 9, 1915, 4 P. M.; ADULTS REMOVED AUG. 10, 4 P. M.

| 1915. | | *Days.* | °F |
|---|---|---|---|
| Aug. 19, 4 p. m. | 11 | 8–10 | 75.15 |
| Aug. 20, 4 p. m. | 16 | 9–11 | 75.00 |
| Aug. 21, 4 p. m. | 5 | 10–12 | 74.87 |
| Aug. 22, 4 p. m. | 3 | 11–13 | 75.07 |
| Average | | 9.5–11.5 | 75.02 |

CAGE NO. 3.—TWENTY-FIVE PAIRS OF ADULTS PLACED ON APPLE TREE AUG. 13, 1915, 4 P. M.; ADULTS REMOVED AUG. 14, 3 P. M.

| 1915. | | *Days.* | °F |
|---|---|---|---|
| Aug. 23, 4 p. m. | 6 | 8–10 | 74.65 |
| Aug. 24, 4 p. m. | 43 | 9–11 | 74.95 |
| Aug. 25, 4 p. m. | 38 | 10–12 | 74.70 |
| Aug. 26, 4 p. m. | 9 | 11–13 | 74.57 |
| Aug. 27, 4 p. m. | 3 | 12–14 | 73.89 |
| Average | | 10–12 | 74.55 |

TABLE XII.—*Length of nymphal stages of the third brood of the apple leafhopper at West Chester, Pa., 1915.*

THIRD BROOD, AUGUST AND SEPTEMBER.

| Date of hatching. | First molt. | First stage. | Second molt. | Second stage. | Third molt. | Third stage. | Fourth molt. | Fourth stage. | Fifth molt. | Fifth stage. | Total nymphal period. | Average mean temperature for nymphal period. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1915. | 1915. | *Days.* | 1915. | *Days.* | 1915. | *Days.* | 1915. | *Days.* | 1915. | *Days.* | *Days.* | °F. |
| Aug. 12 | Aug. 14 | 2 | Aug. 17 | 3 | Aug. 20 | 3 | Aug. 22 | 2 | Aug. 27 | 5 | 15 | 74.44 |
| Do. | Aug. 16 | 4 | Aug. 19 | 3 | Aug. 21 | 2 | Aug. 25 | 4 | Aug. 30 | 5 | 18 | 73.10 |
| Do. | Aug. 15 | 3 | ...do..... | 4 | Aug. 22 | 3 | ...do..... | 3 | Aug. 31 | 6 | 19 | 72.55 |
| Do. | Aug. 16 | 4 | ...do..... | 3 | Aug. 23 | 4 | Aug. 27 | 4 | Sept. 3 | 7 | 22 | 72.32 |
| Aug. 14 | Aug. 15 | 1 | Aug. 18 | 3 | Aug. 21 | 3 | Aug. 24 | 3 | Aug. 30 | 6 | 16 | 72.50 |
| Do. | Aug. 16 | 2 | Aug. 19 | 3 | Aug. 22 | 3 | Aug. 25 | 3 | Aug. 31 | 6 | 17 | 71.94 |
| Do. | ...do..... | 2 | ...do..... | 3 | ...do..... | 3 | ...do..... | 3 | Sept. 1 | 7 | 18 | 71.78 |
| Do. | ...do..... | 2 | ...do..... | 3 | Aug. 23 | 4 | Aug. 27 | 4 | Sept. 2 | 6 | 19 | 71.52 |
| Do. | Aug. 17 | 3 | ...do..... | 2 | Aug. 24 | 5 | Aug. 26 | 2 | Sept. 1 | 6 | 18 | 71.78 |
| Aug. 17 | Aug. 20 | 3 | Aug. 23 | 3 | Aug. 26 | 3 | Aug. 31 | 5 | Sept. 6 | 6 | 20 | 71.76 |
| Do. | ...do..... | 3 | Aug. 22 | 2 | Aug. 25 | 3 | ...do..... | 6 | ...do..... | 6 | 20 | 71.76 |
| Do. | Aug. 21 | 4 | Aug. 23 | 2 | ...do..... | 2 | Sept. 1 | 7 | ...do..... | 5 | 20 | 71.76 |
| Do. | ...do..... | 4 | ...do..... | 2 | Aug. 26 | 3 | ...do..... | 6 | Sept. 7 | 6 | 21 | 72.09 |
| Do. | Aug. 20 | 3 | Aug. 22 | 2 | Aug. 25 | 3 | ...do..... | 7 | Sept. 6 | 5 | 20 | 71.76 |
| Average | ..... | 2.8 | ..... | 2.7 | ..... | 3.1 | ..... | 4.2 | ..... | 5.8 | 18.7 | 72.21 |

THIRD BROOD OF NYMPHS.

*Length of stages.*—The average nymphal period was 18.7 days; the maximum, 22 days; the minimum, 15 days. (See Table XII.)

THIRD BROOD OF ADULTS.

*Attempt to rear a fourth brood of nymphs.*—Third-brood adults which were reared in confinement were placed on young apple trees in globe cages in an attempt to rear a fourth brood of nymphs. Four experiments were carried out, pairs of adults being confined on August 24, September 14 and 30, and October 1. None of the adults was observed to mate and not a single fourth-brood nymph developed. The foliage was examined several times covering a period of six weeks or more after the adults were confined.

*Number of winter eggs deposited.*—Four globe cage experiments were conducted to determine whether the third and last brood adults of the apple leafhopper deposited winter eggs in the bark of apple trees. Pairs of adults were confined in four separate cages on August 24, September 14, September 30, and October 1. They were allowed to remain undisturbed on the trees until December 10, when the trees were brought into the laboratory and carefully examined for winter eggs under the bark. Not a single winter egg was found on any of the four trees.

TABLE XIII.—*Daily maximum, minimum, and average temperatures taken at West Chester, Pa., from May 12 to Sept. 18, 1915.*

| Day of month. | May. | | | June. | | | July. | | | August. | | | September. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. |
| | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. |
| 1 | ..... | ..... | ..... | 80 | 64 | 72 | 86 | 76 | 81 | 96 | 82 | 89 | 72 | 66 | 69 |
| 2 | ..... | ..... | ..... | 60 | 54 | 57 | 84 | 68 | 76 | 91 | 79 | 85 | 73 | 66 | 69.5 |
| 3 | ..... | ..... | ..... | 59 | 48 | 53.5 | 88 | 76 | 82 | 75 | 67 | 71 | 81 | 66 | 73.5 |
| 4 | ..... | ..... | ..... | 80 | 59 | 69.5 | 84 | 75 | 79.5 | 84 | 76 | 80 | 83 | 72 | 77.5 |
| 5 | ..... | ..... | ..... | 84 | 70 | 77 | 80 | 72 | 76 | 83 | 77 | 80 | 84 | 74 | 79 |
| 6 | 74 | 67 | 70.5 | 75 | 70 | 72.5 | 76 | 68 | 72 | 80 | 70 | 75 | 86 | 76 | 81 |
| 7 | 77 | 65 | 71 | 84 | 71 | 77.5 | 82 | 72 | 77 | 68 | 63 | 65.5 | 86 | 74 | 80 |
| 8 | 70 | 60 | 65 | 80 | 70 | 75 | 80 | 68 | 74 | 84 | 72 | 78 | 86 | 71 | 78.5 |
| 9 | 63 | 54 | 58.5 | 76 | 66 | 71 | 83 | 66 | 74.5 | 82 | 70 | 76 | 86 | 78 | 82 |
| 10 | 66 | 55 | 60.5 | 76 | 61 | 68.5 | 86 | 76 | 81 | 80 | 70 | 75 | 90 | 76 | 83 |
| 11 | 68 | 58 | 63 | 84 | 74 | 79 | 80 | 73 | 76.5 | 80 | 72 | 76 | 86 | 78 | 82 |
| 12 | 72 | 60 | 66 | 88 | 75 | 81.5 | 87 | 72 | 79.5 | 79 | 71 | 75 | 84 | 74 | 79 |
| 13 | 80 | 59 | 69.5 | 86 | 78 | 82 | 84 | 75 | 79.5 | 85 | 78 | 81.5 | 88 | 82 | 85 |
| 14 | 81 | 60 | 70.5 | 89 | 76 | 82.5 | 85 | 71 | 78 | 84 | 73 | 78.5 | 88 | 80 | 84 |
| 15 | 79 | 54 | 66.5 | 84 | 72 | 78 | 84 | 74 | 79 | 84 | 74 | 79 | 86 | 80 | 83 |
| 16 | 62 | 50 | 56 | 83 | 75 | 79 | 89 | 74 | 81.5 | 85 | 77 | 81 | 88 | 76 | 82 |
| 17 | 71 | 62 | 66.5 | 84 | 74 | 79 | 91 | 83 | 87 | 75 | 68 | 71.5 | 88 | 74 | 81 |
| 18 | 61 | 50 | 55.5 | 83 | 77 | 80 | 92 | 82 | 87 | 70 | 58 | 64 | 81 | 70 | 75.5 |
| 19 | 74 | 52 | 63 | 83 | 76 | 79.5 | 90 | 82 | 86 | 76 | 64 | 70 | ..... | ..... | ..... |
| 20 | 75 | 64 | 69.5 | 80 | 73 | 76.5 | 79 | 72 | 75.5 | 82 | 65 | 73.5 | ..... | ..... | ..... |
| 21 | 66 | 59 | 62.5 | 77 | 65 | 71 | 78 | 68 | 73 | 76 | 71 | 73.5 | ..... | ..... | ..... |
| 22 | 84 | 69 | 76.5 | 65 | 60 | 62.5 | 84 | 74 | 79 | 83 | 72 | 77.5 | ..... | ..... | ..... |
| 23 | 72 | 66 | 69 | 69 | 61 | 65 | 81 | 68 | 74.5 | 83 | 73 | 78 | ..... | ..... | ..... |
| 24 | 70 | 58 | 64 | 75 | 60 | 67.5 | 80 | 74 | 77 | 84 | 72 | 78 | ..... | ..... | ..... |
| 25 | 76 | 68 | 72 | 81 | 66 | 73.5 | 84 | 74 | 79 | 76 | 68 | 72 | ..... | ..... | ..... |
| 26 | 77 | 60 | 68.5 | 84 | 69 | 76.5 | 84 | 72 | 78 | 76 | 70 | 73 | ..... | ..... | ..... |
| 27 | 79 | 64 | 71.5 | 78 | 68 | 73 | 82 | 69 | 75.5 | 70 | 60 | 65 | ..... | ..... | ..... |
| 28 | 70 | 66 | 68 | 78 | 65 | 71.5 | 82 | 74 | 78 | 66 | 62 | 64 | ..... | ..... | ..... |
| 29 | 69 | 63 | 66 | 78 | 67 | 72.5 | 86 | 78 | 82 | 66 | 60 | 63 | ..... | ..... | ..... |
| 30 | 79 | 71 | 75 | 80 | 75 | 77.5 | 90 | 80 | 85 | 74 | 68 | 71 | ..... | ..... | ..... |
| 31 | 80 | 70 | 75 | ..... | ..... | ..... | 91 | 74 | 82.5 | 68 | 57 | 62.5 | ..... | ..... | ..... |

The foregoing experiments indicate that third-brood adults of the apple leafhopper, under Pennsylvania conditions, do not deposit winter eggs, but merely feed on the foliage until the time arrives for them to seek shelter for the winter.

The daily temperature for the period of seasonal activity is given in Table XIII.

### SUMMARY OF SEASONAL HISTORY.

The apple leafhopper passes the winter in the adult stage under rubbish in the nursery or more often under accumulations of leaves in adjoining woodlands. In the spring the overwintered adults make their appearance on the trees during the latter part of May and they feed on the underside of the terminal leaves for about 10 days before mating. The females deposit their eggs in the veins of the terminal leaves, the average length of the incubation period of the first-brood eggs being approximately one week. The feeding period of this brood of nymphs extends from May 30 until about the middle of July, the nymphs being most abundant during the third week in June. The length of the first-brood nymphal period varies from 15 to 22 days, the average being 18.7 days. First-brood adults continue to emerge from June 20 to July 20. (See fig. 2.)

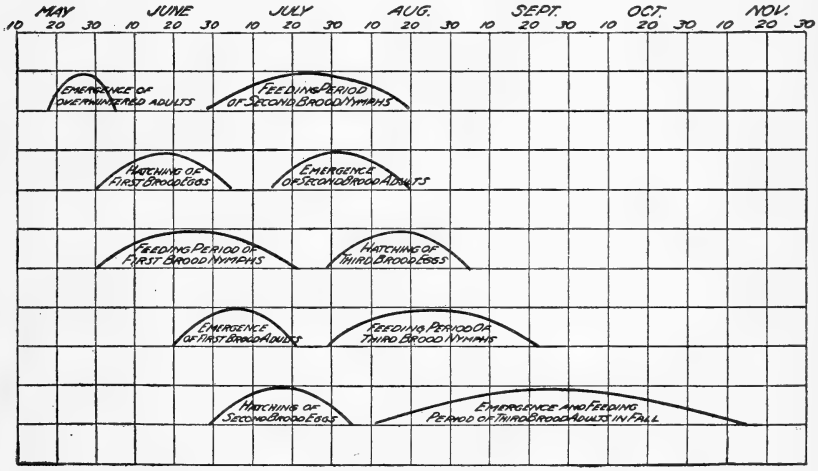



FIG. 2.—Seasonal history of the apple leafhopper at West Chester, Pa., 1915.

Second-brood eggs hatch from the latter part of June until about August 1, the length of the incubation period being about one week. The second-brood nymphs commence to appear about the last part of June, the larger percentage having developed into adults by the middle of August. The average length of the second nymphal period is 15.8 days; the maximum and minimum, 17 and 15 days, respectively. Second-brood adults appear on the trees from the middle of July until about a month later.

The third-brood eggs hatch from July 30 until about September 1, the length of the egg stage of this brood being about 9 to 10 days. Third-brood nymphs are found on the foliage from August 1 until about the third week in September, the average length of the entire nymphal period being 18.7 days or approximately the same as that of the first brood. By the middle of August the nymphs begin to transform to adults and by the end of September all the nymphs have disappeared. The third-brood adults remain on the trees until cold weather sets in when they gradually disperse to the hibernating places.

#### NATURAL ENEMIES.

The apple leafhopper is evidently quite free from the attack of parasites. Only one record of parasitism has appeared in the literature, R. L. Webster in 1913 having noted the pupa of an egg parasite which, however, died before reaching maturity.

A few cases of parasitism of adults by a dryinid have been seen at West Chester, Pa., but no adults of this parasite were reared successfully. However, two dryinid females were captured in the field while in the act of ovipositing in the abdomen of nymphs of *Empoasca mali*. These specimens were determined by Mr. J. C. Crawford, of the United States National Museum, as *Aphelopus albopictus* Ashm.

Probably the most effective enemy of this leafhopper is the predacious heteropteron *Triphleps insidiosus* Say. This small black insect, which is rather common on the foliage during midsummer, feeds on the nymphs by thrusting its beak into their soft bodies. It is actually of little importance, however, in reducing the numbers of leafhopper nymphs.

Spiders and various species of mites have been noted attacking and devouring nymphs on several occasions. In one instance an adult of the pear-leaf blister-mite was found preying on a first-stage nymph. Ladybeetle larvæ also are predacious on nymphs to a small extent.

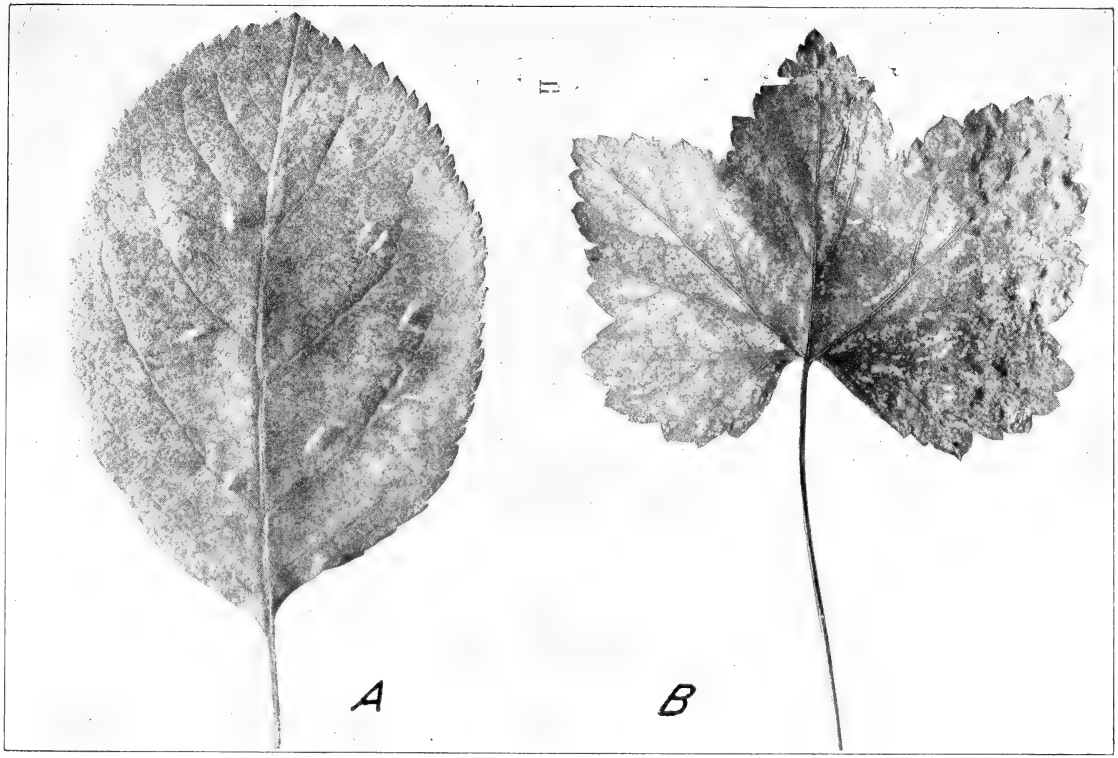
R. L. Webster (18) records larvæ of aphis lions and a dipteron of the family Empididae as feeding on the nymphs in Iowa.

As in the case of other species of leafhoppers, both the nymphs and the adults are often caught in spider webs.

### THE ROSE LEAFHOPPER, Empoa rosae (Linn.).

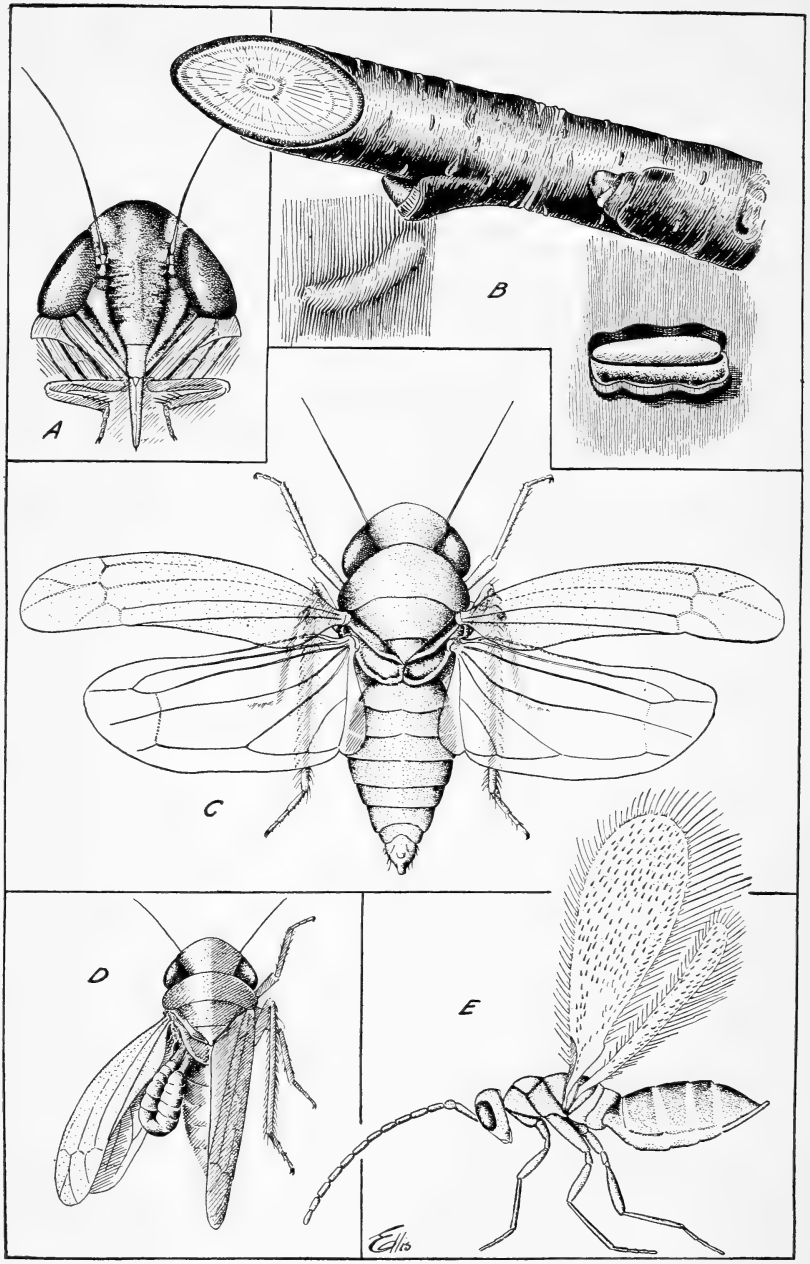
#### HISTORY.

The rose leafhopper was originally described by Linnaeus (21, p. 439) in Europe in 1758 as *Cicada rosae*. Since that time this insect has been placed in several genera by various writers in Europe and North America. It was first listed by Burmeister in 1835 as *Typhlocyba rosae* Linn., and under this name it has been commonlyknown in




THE ROSE LEAFHOPPER (EMPOA ROSAE).

*A*, Typical injury to apple leaf caused by the rose leafhopper; *B*, injury to currant leaf.




## THE ROSE LEAFHOPPER.

*A*, Front view of head of male; *B*, overwintering eggs under bark of apple twig; *C*, adult with wings spread; *D*, adult with larva of dryinid parasite protruding from the body; *E*, *Anagrus armatus nigriventris*, parasite of winter egg.

entomological literature. The genus Empoa was erected by Fitch (22, p. 63) in 1851, and in 1889 Weed (25, p. 155) transferred *rosae* from Typhlocyba to Empoa. In recent years *rosae*, with a few exceptions, has been referred to under the genus Typhlocyba, owing to the persistant ignoring of Empoa Fitch.

This insect has been known as a pest of cultivated roses in several European countries for more than a hundred years. The first account of the rose leafhopper in this country was published by Harris (23, p. 199) in 1852, when he described it as *Tettigonia rosae*. Although brief mention has been frequently made of this hopper since Harris's time, the first record of it as an enemy of apple was made by Parrott (26) in 1909. Wilson and Childs (27) in 1915 were the first authors to treat of this insect at any length. They made a study of the rose leafhopper as a fruit pest in Oregon, giving the life history, habits, destructiveness, and remedial measures. Brittain (28), also in 1915, discussed this species as an enemy of apple in Nova Scotia.

### SYNONYMY.

**Empoa rosae (Linn.).**

*Cicada rosae* Linn. Syst. Nat., ed. 10, v. 1, 1758, p. 439.
*Typhlocyba rosae* Burm. Handb. d. Ent., 2, 1835, p. 107.
*Cicadula rosae* Zett. Ins. Lap., 1840, p. 299.
*Typhlocyba pteridis* Dahlb. Kongl. Vet.-Akad. Handl., 1850, p. 179.
*Tettigonia rosae* Harr. Ins. Inj. to Veg., 2nd ed., 1852, p. 199.
*Eupteryx rosae* Marsh. Ent. Mo. Mag., v. 3, 1866–1867, p. 246.
*Typhlocyba lactea* Dougl. Ent. Mo. Mag., v. 12, 1875, p. 77.
*Anomia rosae* Fieber. Rev. d'Ent., v. 3, 1884, p. 124.
*Empoa rosae* Weed. Amer. Gard., July, 1889, p. 257.

### ORIGIN AND DISTRIBUTION.

The rose leafhopper is undoubtedly of European origin, as it was known to Linnaeus more than a century before it was first recorded in this country. It probably was introduced from abroad in the egg stage on rose or apple stock.

It is distributed generally throughout the United States and has been taken from States forming the extreme northern, southern, eastern, and western limits of the country. It is apparently most abundant in the Northern States, particularly in the Pacific Northwest. In Canada, this insect has been reported from Nova Scotia, Ontario Province, and from British Columbia. In Europe it has been recorded from several localities in England, France, and Germany.

### FOOD PLANTS.

This insect, although primarily a pest of rose and apple, is a rather general feeder. At West Chester, Pa., it has been taken feeding upon rose, apple, pear, peach, plum, cherry, quince, currant, gooseberry, raspberry, blackberry, grape, Crataegus, elm, oak, and cotton-

wood (*Platanus deltoides*). In addition, Wilson and Childs list strawberry, logan blackberry, and prune from Oregon. It is likely that this leafhopper will feed on the foliage of most plants belonging to the family Rosaceae.

### CHARACTER OF INJURY.

The nymphs and adults of *Empoa rosae* confine their feeding entirely to the lower leaves of apple trees in the nursery. They congregate on the lower surfaces of the foliage and suck the plant juices by puncturing the leaf tissue with their tiny beaks. The first indication of the injury is the mottling of the leaves with yellowish or whitish spots at the points where the punctures were made. (See Pl. IV.) When the leaves become heavily infested they turn yellow, dry up, and drop to the ground prematurely. The foliage is never curled by this species, nor is the terminal growth checked, as in the case of injury by *Empoasca mali*.

A second type of injury is produced by the egg punctures made by the females in the fall during the oviposition period. The eggs are deposited under the bark of young apple trees, several hundred eggs often being placed in a single twig.

The injury produced by the rose leafhopper to apple nursery stock is of little importance, however, when compared with that caused by the more destructive apple leafhopper.

### DESCRIPTION OF STAGES.

#### EGG.

Pl. V, B.

The winter egg is elongate oval, slightly crescentic in form, almost circular in cross section, and blunt at both ends. It is almost transparent at first, but when ready to hatch it changes to a milky white color, while the red eyes of the young nymph are visible through the smooth chorion.

Average length of 16 eggs 0.65 mm., width 0.19 mm.

#### NYMPH.

*First instar.*—Color of first-instar nymph pale white changing to light yellow after feeding. Eyes dull red. Small spines present on the dorsal side of the head, thorax, and abdomen; the latter with four spines to each segment arranged in two longitudinal rows on each side. Posterior margin of metathorax blunt. First two segments of antennæ pale, remainder dusky. Average length of 16 specimens 0.98 mm.

*Second instar.*—General color creamy white to light yellow. Eyes lose some of their red color, becoming lighter. Wing pads begin to appear as lateral buds. Posterior margin of metathorax sharp in outline. First two segments of antennae yellow, remainder dusky. Average length of 16 specimens 1.27 mm.

*Third instar.*—General color light yellow. Eyes dull white. Body more robust than in first two stages. Wing pads extending to hind margin of the first abdominal segment. Spines darker and more prominent. Average length of 16 specimens 1.55 mm.

*Fourth instar.*—General color light yellow. Eyes almost pearl white with a brown central spot underneath. Wing pads extending to hind margin of the second abdominal segment. Spines very distinct. Average length of 16 specimens 2.03 mm.

*Fifth instar.*—General color as in previous stage. Eyes almost pearl white. Wing pads extending nearly to the hind margin of the fourth abdominal segment. Broader than in previous stage. Average length of 16 specimens 2.85 mm.

### THE ADULT.

Pl. V, A, C.

General color of adult creamy white to light yellow. Head rather pointed, pale yellow; face of male with a tint of orange color in the form of a central longitudinal stripe with several transverse radiating stripes; genæ pale, narrow, and almost as long as clypeus; loræ very narrow, sunken beneath the compound eyes. Vertex pale yellow with two semitransparent spots just above the ocelli, a faint median longitudinal semitransparent line extending from the hind margin half-way to the front margin, and a semitransparent line bordering each eye. Two ocelli present, situated on the frontal margin of the vertex, marked by two white spots with a dark center, distance apart twice that from the eye to the ocellus; eyes pearl white with a darkened center, ashen-gray after death. Pronotum light yellow with a semitransparent area in the center; mesonotum semitransparent with a large trapezoidal creamy area extending from the front to the hind margins, wider behind; a small cream colored area anteriorly on each side; scutellum cream-colored, sometimes with a semitransparent area caudad. Elytra transparent. First two segments of antennæ pale, flagellum dusky. Legs pale, tarsi dusky at tips. Sexual appendages slightly ciliated in female only. Average length of 12 specimens 3.00 mm.

## LIFE HISTORY AND HABITS.

### THE EGG.

Part of the rearing work in the life history of the rose leafhopper was conducted during the spring of 1915, the work being completed during the season of 1916. In obtaining data on the biology of this insect the same methods as devised for the study of the apple leafhopper were used.

*Winter egg.*—This leafhopper hibernates in the egg stage, winter eggs being deposited in the fall during the period extending from the last week in September to November 1. They are laid almost entirely under the bark of apple trees and rose bushes, though a few have been found in pear, quince, cherry, plum, currant, and Crataegus. The eggs are deposited singly, usually lying in a longitudinal position just under the epidermis, and they are placed in a distinct blister or pouch which measures 0.7 to 0.8 mm. in length. They are easily located by looking on the bark for the raised blister, which, as a rule, is slightly crescentic in outline. Winter eggs have been found in the bark of nursery apple trees from one to four years old; they are found in greatest numbers on the first year's growth of two-year trees. The favorite location for oviposition seems to be around the bases of the lowest limbs or on the trunk just below the first branches.

*Summer eggs.*—Summer eggs are laid by first-brood adults during July in the veins of the lower leaves.

### The Nymph.

The nymphs of this species differ from those of *Empoasca mali* by their paler color, by their smaller size, and by the fact that they confine their activities entirely to the lower leaves of the trees. Though very active they are not quite as quick in their movements as the nymphs of the apple leafhopper.

As the young nymphs emerge from the eggs in the bark they make their way to the nearest leaves, where they immediately settle down to feed. In the vicinity of West Chester, Pa., the first nymphs of the season emerge about May 1, and by May 15 practically all the winter eggs have hatched. Generally speaking, the nymphs of this species are from three to four weeks old before the first nymphs of *Empoasca mali* appear on the terminal leaves.

### The Adult.

Nymphs of the first brood transform to adults during the first two weeks in June and these adults feed on the foliage for several weeks before mating. Oviposition extends over a period of about two weeks during late June and early July, most of the first-brood adults dying by the end of July.

Second-brood adults begin to appear during the first week in August, and they remain on the trees until death, which occurs by November 1, after the winter eggs have been deposited. A few adults have been noticed on the trees as late as November 25. No rose leafhoppers, either in confinement or in the field, were observed to hibernate in the adult stage.

### First Generation.

#### first brood of eggs.

The length of the incubation period of the first-brood eggs (i. e., the winter eggs) is 6 to 7 months. Eggs deposited during October hatch by the middle of May of the following year at the latest.

#### first brood of nymphs.

Nymphs newly hatched from winter eggs were confined in individual cork cages on uninfested leaves. The average length of the entire nymphal period, as indicated in Table XIV, was 33.4 days; the maximum, 36 days; the minimum, 30 days.

TABLE XIV.—*Length of nymphal stages of the first brood of the rose leafhopper on nursery apple trees at West Chester, Pa., 1915.*

First brood, May and June.

| Date of hatching. | First molt. | First stage. | Second molt. | Second stage. | Third molt. | Third stage. | Fourth molt. | Fourth stage. | Fifth molt. | Fifth stage. | Total nymphal period. | Average mean temperature for nymphal period. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1915. | 1915. | *Days.* | 1915. | *Days.* | 1915. | *Days.* | 1915. | *Days.* | 1915. | *Days.* | *Days.* | *°F.* |
| May 6 | May 11 | 5 | May 14 | 3 | May 21 | 7 | May 28 | 7 | June 7 | 10 | 32 | 67.19 |
| May 7 | May 13 | 6 | May 17 | 4 | May 24 | 7 | May 30 | 6 | June 8 | 9 | 32 | 67.33 |
| Do | May 14 | 7 | May 21 | 7 | May 29 | 8 | June 4 | 6 | June 12 | 8 | 36 | 68.16 |
| Do | do | 7 | May 22 | 8 | May 28 | 6 | June 2 | 5 | June 10 | 8 | 34 | 67.47 |
| Do | May 15 | 8 | do | 7 | do | 6 | June 3 | 6 | June 11 | 8 | 35 | 67.79 |
| Do | May 12 | 5 | May 20 | 8 | May 26 | 6 | do | 8 | June 9 | 6 | 33 | 67.44 |
| Do | May 16 | 9 | May 23 | 7 | May 29 | 6 | June 5 | 7 | June 12 | 7 | 36 | 68.16 |
| Do | May 15 | 8 | do | 8 | May 30 | 7 | June 4 | 5 | June 11 | 7 | 35 | 67.79 |
| May 8 | May 13 | 5 | May 21 | 8 | May 27 | 6 | June 3 | 7 | do | 8 | 34 | 67.70 |
| May 11 | May 16 | 5 | do | 5 | do | 6 | do | 7 | June 10 | 7 | 30 | 67.85 |
| Do | May 17 | 6 | May 22 | 5 | May 28 | 6 | do | 6 | June 11 | 8 | 31 | 68.29 |
| Average | | 6.4 | | 6.3 | | 6.4 | | 6.3 | | 7.8 | 33.4 | 67.74 |

FIRST BROOD OF ADULTS.

No attempt was made to obtain definite data on the longevity of first-brood adults. Ninety adults, however, were confined in a Riley cage on a young apple tree on May 31, 1916, and the last leafhoppers died on August 1; by this date many of the second-brood nymphs had appeared. Thus, the length of life of the adults of this brood is approximately two months.

## SECOND GENERATION.

### SECOND BROOD OF EGGS.

*Length of incubation period.*—An approximation of the length of the egg stage of second-brood eggs (i. e., the summer eggs) is shown in Table XV. The average length of the period was 25 days; the maximum, 27 days; the minimum, 23 days.

TABLE XV.—*Length of incubation period of summer eggs deposited by first-brood females of the rose leafhopper, West Chester, Pa., 1916.*

Four pairs of adults placed in confinement on apple tree July 28, 1916, 4 p. m.; adults removed July 29, 4 p. m.

| Date of removal of newly hatched nymphs. | Number of nymphs removed. | Incubation period. | Date of removal of newly hatched nymphs. | Number of nymphs removed. | Incubation period. |
|---|---|---|---|---|---|
| 1916. | | *Days.* | 1916. | | *Days.* |
| Aug. 21 | 0 | | Aug. 25 | 0 | |
| Aug. 22 | 9 | 23–25 | Aug. 26 | 0 | |
| Aug. 23 | 2 | 24–26 | Aug. 27 | 0 | |
| Aug. 24 | 2 | 25–27 | Aug. 28 | 0 | |

SECOND BROOD OF NYMPHS.

*Length of stages.*—In Table XVI the length of the stages and of the entire nymphal period is recorded. The average length of the nymphal period was 17.7 days; the maximum, 19 days; the minimum, 16 days. It will be noted that the length of the nymphal period of the second brood was much shorter and that the corresponding temperatures were much higher than in the case of the first-brood nymphs.

TABLE XVI.—*Length of nymphal stages of second brood of the rose leafhopper on nursery apple trees at West Chester, Pa., 1916.*

Second brood, July and August.

| Date of hatching. | First molt. | First stage. | Second molt. | Second stage. | Third molt. | Third stage. | Fourth molt. | Fourth stage. | Fifth molt. | Fifth stage. | Total nymphal period. | Average mean temperature for nymphal period. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1916. | 1916. | *Days.* | 1916. | *Days.* | 1916. | *Days.* | 1916. | *Days.* | 1916. | *Days.* | *Days.* | °*F.* |
| July 21 | July 25 | 4 | July 28 | 3 | July 31 | 3 | Aug. 3 | 3 | Aug. 7 | 4 | 17 | 79.72 |
| July 24 | July 28 | 4 | July 31 | 3 | Aug. 4 | 4 | Aug. 6 | 2 | Aug. 10 | 4 | 17 | 80.13 |
| July 25 | July 27 | 2 | ...do..... | 4 | Aug. 3 | 3 | ...do..... | 3 | ...do..... | 4 | 16 | 80.38 |
| Do... | July 28 | 3 | Aug. 1 | 4 | Aug. 5 | 4 | Aug. 7 | 2 | Aug. 12 | 5 | 18 | 80.55 |
| Do... | July 31 | 6 | Aug. 3 | 3 | ...do..... | 2 | Aug. 8 | 3 | ...do..... | 4 | 18 | 80.55 |
| July 28 | ...do..... | 3 | Aug. 4 | 4 | Aug. 6 | 2 | Aug. 9 | 3 | Aug. 15 | 6 | 18 | 79.84 |
| Do... | Aug. 1 | 4 | ...do..... | 3 | ...do..... | 2 | ...do..... | 3 | ...do..... | 6 | 18 | 79.84 |
| Do... | ...do..... | 4 | ...do..... | 3 | ...do..... | 2 | Aug. 10 | 4 | Aug. 16 | 6 | 19 | 79.70 |
| Do... | ...do..... | 4 | Aug. 5 | 4 | Aug. 8 | 3 | Aug. 12 | 4 | Aug. 15 | 3 | 18 | 79.84 |
| July 30 | Aug. 2 | 3 | Aug. 6 | 4 | ...do..... | 2 | ...do..... | 4 | Aug. 17 | 5 | 18 | 80.26 |
| Do... | Aug. 4 | 5 | ...do..... | 2 | Aug. 10 | 4 | Aug. 15 | 5 | Aug. 18 | 3 | 19 | 80.40 |
| Do... | Aug. 2 | 3 | ...do..... | 4 | Aug. 9 | 3 | Aug. 13 | 4 | ...do..... | 5 | 19 | 80.40 |
| July 31 | Aug. 5 | 5 | Aug. 9 | 4 | Aug. 12 | 3 | Aug. 16 | 4 | Aug. 19 | 3 | 19 | 80.75 |
| Do... | ...do..... | 5 | Aug. 8 | 3 | ...do..... | 4 | Aug. 15 | 3 | ...do..... | 4 | 19 | 80.75 |
| Aug. 3 | Aug. 6 | 3 | Aug. 10 | 4 | Aug. 13 | 3 | Aug. 16 | 3 | Aug. 20 | 4 | 17 | 80.94 |
| Aug. 4 | Aug. 7 | 3 | Aug. 9 | 2 | ...do..... | 4 | Aug. 17 | 4 | Aug. 21 | 4 | 17 | 81.38 |
| Do... | Aug. 6 | 2 | Aug. 11 | 5 | Aug. 15 | 4 | Aug. 18 | 3 | ...do..... | 3 | 17 | 81.38 |
| Do... | Aug. 8 | 4 | Aug. 12 | 4 | ...do..... | 3 | Aug. 17 | 2 | Aug. 20 | 3 | 16 | 81.23 |
| Do... | ...do..... | 4 | Aug. 13 | 5 | Aug. 16 | 3 | Aug. 19 | 3 | Aug. 22 | 3 | 18 | 81.68 |
| Aug. 5 | ...do..... | 3 | Aug. 11 | 3 | Aug. 15 | 4 | Aug. 17 | 2 | Aug. 21 | 4 | 16 | 81.29 |
| Average..... | | 3.7 | ..... | 3.5 | ..... | 3.1 | ..... | 3.2 | ..... | 4.1 | 17.7 | 80.50 |

SECOND BROOD OF ADULTS.

*Extent of reproduction.*—Pairs of second-brood adults were confined in arc-light globe cages to determine the number of winter eggs deposited per female in the bark of apple. The data in Table XVII were obtained in the fall of 1915, and that in Table XVIII in 1916. The hoppers were allowed to remain on the trees until death. The average number of eggs deposited per female during the two experiments was 15.5 and 16, respectively.

*Attempt to rear a third brood of nymphs.*—A globe-cage experiment was conducted to determine whether second-brood adults would produce a third brood of nymphs. Ten pairs were confined on August 7 in two cages and examined at intervals until October 1. In no case

did any third-brood nymphs develop, only winter eggs being deposited by the females.

TABLE XVII.—*Number of winter eggs deposited in bark of apple trees by second-brood adults in confinement, West Chester, Pa., 1915.*

| Cage. | Date of confinement. | Number of pairs confined. | Date of examination. | Number of eggs present. |
|---|---|---|---|---|
| | 1915. | | 1915. | |
| 1 | Sept. 26 | 6 | Nov. 25 | 98 |
| 2 | Oct. 9 | 5 | ...do | 78 |
| | Total | | | 176 |
| | Average per female | | | 16 |

TABLE XVIII.—*Number of winter eggs deposited in bark of apple trees by second-brood adults in confinement, West Chester, Pa., 1916.*

| Cage. | Date of confinement. | Number of pairs confined. | Date of examination. | Number of eggs present. |
|---|---|---|---|---|
| | 1916. | | 1916. | |
| 1 | Aug. 7 | 6 | Nov. 7 | 104 |
| 2 | Sept. 6 | 9 | Nov. 8 | 129 |
| | Total | | | 233 |
| | Average per female | | | 15.5 |

In Table XIX the daily temperature is given for the period of seasonal activity, 1916.

TABLE XIX.—*Daily maximum, minimum, and average temperature taken at West Chester, Pa., from July 21 to Oct. 31, 1916.*

| Day of month. | July. | | | August. | | | September. | | | October. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. |
| 1916. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. |
| 1 | | | | 85 | 74 | 79.5 | 84 | 78 | 81 | 53 | 45 | 49 |
| 2 | | | | 80 | 70 | 75 | 81 | 76 | 78.5 | 65 | 50 | 57.5 |
| 3 | | | | 78 | 74 | 76 | 72 | 66 | 69 | 70 | 53 | 61.5 |
| 4 | | | | 88 | 78 | 83 | 78 | 70 | 74 | 65 | 61 | 63 |
| 5 | | | | 88 | 77 | 82.5 | 83 | 72 | 77.5 | 75 | 59 | 67 |
| 6 | | | | 92 | 80 | 86 | 84 | 76 | 80 | 73 | 65 | 69 |
| 7 | | | | 91 | 82 | 86.5 | 86 | 78 | 82 | 70 | 62 | 66 |
| 8 | | | | 92 | 75 | 83.5 | 88 | 74 | 81 | 77 | 60 | 68.5 |
| 9 | | | | 85 | 76 | 80.5 | 76 | 68 | 72 | 82 | 70 | 76 |
| 10 | | | | 82 | 68 | 75 | 74 | 66 | 70 | 53 | 43 | 48 |
| 11 | | | | 86 | 78 | 82 | 72 | 60 | 66 | 62 | 50 | 56 |
| 12 | | | | 86 | 78 | 82 | 76 | 61 | 68.5 | 70 | 58 | 64 |
| 13 | | | | 74 | 70 | 72 | 81 | 65 | 73 | 56 | 54 | 55 |
| 14 | | | | 78 | 72 | 75 | 84 | 72 | 78 | 60 | 52 | 56 |
| 15 | | | | 80 | 74 | 77 | 72 | 64 | 68 | 60 | 45 | 52.5 |
| 16 | | | | 80 | 74 | 77 | 66 | 56 | 61 | 62 | 59 | 60.5 |
| 17 | | | | 90 | 80 | 85 | 70 | 62 | 66 | 68 | 60 | 64 |
| 18 | | | | 86 | 80 | 83 | 68 | 60 | 64 | 58 | 44 | 51 |
| 19 | | | | 90 | 82 | 86 | 62 | 51 | 56.5 | 67 | 56 | 61.5 |
| 20 | | | | 88 | 82 | 85 | 72 | 57 | 64.5 | 80 | 68 | 74 |
| 21 | 80 | 72 | 76 | 93 | 75 | 84 | 72 | 56 | 64 | 57 | 49 | 53 |
| 22 | 81 | 70 | 75.5 | 92 | 82 | 87 | 75 | 64 | 69.5 | 54 | 45 | 49.5 |
| 23 | 84 | 76 | 80 | 92 | 82 | 87 | 76 | 68 | 72 | 56 | 44 | 50 |
| 24 | 78 | 74 | 76 | 79 | 69 | 74 | 68 | 55 | 61.5 | 61 | 48 | 54.5 |
| 25 | 76 | 74 | 75 | 84 | 66 | 75 | 66 | 57 | 61.5 | 64 | 46 | 55 |
| 26 | 82 | 78 | 80 | 84 | 75 | 79.5 | 72 | 57 | 64.5 | 56 | 48 | 52 |
| 27 | 90 | 75 | 82.5 | 86 | 74 | 80 | 79 | 66 | 72.5 | 58 | 49 | 53.5 |
| 28 | 80 | 74 | 77 | 70 | 64 | 67 | 82 | 70 | 76 | 56 | 49 | 52.5 |
| 29 | 80 | 74 | 77 | 74 | 64 | 69 | 72 | 56 | 64 | 61 | 46 | 53.5 |
| 30 | 84 | 74 | 79 | 80 | 66 | 73 | 59 | 46 | 52.5 | 67 | 50 | 58.5 |
| 31 | 92 | 85 | 88.5 | 82 | 65 | 73.5 | | | | 62 | 50 | 56 |

### SUMMARY OF SEASONAL HISTORY.

There are two generations of the rose leafhopper annually at West Chester, Pa. This insect hibernates in the egg stage, the eggs being deposited under the bark of the host plants. On apple stock in the nursery the winter eggs hatch from May 1 to May 15, and the newly hatched nymphs immediately attack the lower leaves of the trees. The feeding period of the first brood of nymphs covers approximately one month. The first adults of the season appear by the end of May. The latter feed for several weeks before mating and depositing the second brood of eggs in the foliage. The length of the life of the first-brood adults is about two months, most of them having disappeared by the first week in August.

The length of the incubation period of the second-brood eggs is about 25 days, the first eggs hatching about July 20. Due to the higher temperatures, the length of the nymphal period of this brood is comparatively shorter than that of the spring brood of nymphs. Second-brood nymphs, on an average, attain the adult stage in 17 days. By the latter part of August, practically all the nymphs have transformed to adults. The adults feed for about a month before mating, which takes place during the latter part of September. Females deposit the winter eggs throughout the month of October, soon after which they die. The last adults of the season were found on the trees on November 25.

### NATURAL ENEMIES.

The most efficient enemies of the rose leafhopper are two species of hymenopterous egg parasites belonging to the superfamily Proctotrypoidea. Thesepar asites were determined by Mr. A. A. Girault, of the Bureau of Entomology, as *Anagrus epos* Girault and *Anagrus armatus* Ashm. var. *nigriventris* Girault. (See Pl. V, E.) These two parasites were reared from the winter eggs only, and they emerged both in the fall and in the spring. In the fall they emerged from October 15 to November 1, while in the spring they were reared in abundance about one or two weeks after the hatching of the winter eggs.

These egg parasites are a valuable factor in reducing the destructive numbers of the leafhopper. At West Chester, Pa., from 65 to 70 per cent of the winter eggs were parasitized during 1916. Both of these species evidently are widely distributed, as they have been reared from the eggs in apple twigs from Hagerstown, Md., Winchester, Va., and Roswell, N. Mex.

Adults of this leafhopper are parasitized quite heavily by a species of the family Dryinidae. A rose leafhopper parasitized by a dryinid (Pl. V, D) is readily recognized by the distorted appearance of one of its wings under which the parasitic larva is noticed protruding

from the abdomen. Numerous parasitized leafhoppers were collected but no adult parasites were reared successfully.

A. Giard (24), in 1889, reported the dryinid *Aphelopus melaleucus* Dalm. and the pipunculid *Ateleneura spuria* Meig. as parasites of *Typhlocyba rosae* in France.

Among the predacious enemies of this insect, mites, spiders, and coccinellid and syrphid larvæ have been noted feeding on the nymphs to a limited extent.

Wilson and Childs (27), in 1915, recorded the larva of a green lacewing, *Chrysopa* sp., as preying on young nymphs in Oregon. The same authors list a dragonfly and a scatophagidfly as predacious enemies of adults.

## REMEDIAL MEASURES.

The apple leafhopper, *Empoasca mali*, is one of the most difficult of all leafhoppers to combat successfully, especially because of the wide range of its food plants. In nurseries, however, this species confines its attack chiefly to the foliage of the apple, and if the hoppers can be reduced in sufficient numbers on this plant the danger of infestation from other host plants will be very small.

Little actual work has been done in dealing with the remedial measures to be used against this pest. One of the most frequently recommended methods which many writers have suggested as a means of controlling this leafhopper in nurseries is the use of sticky shields to catch the winged adults as they are jarred from the trees along the nursery row. The use of such a device has never proved satisfactory and it is impracticable when employed on a large scale.

Spraying with contact insecticides against the apple leafhopper has been generally advised. Weiss (19) suggested spraying with 1 pint of "black-leaf 40" to 100 gallons of Pyrox. But in general the recommendations have been so indefinite and vague that little value can be attached to them. In order to clear up the confusion which has existed in regard to the treatment for this insect, spraying experiments, based on the life-history studies, were carried out.

### SPRAYING FOR THE FIRST BROOD.

Spraying experiments against the nymphs were conducted in the nursery of Hoopes Bros. & Thomas Co. at West Chester, Pa. Tests on a small scale were made, the spray being applied with a compressed-air sprayer and an angle nozzle at a pressure of 60 pounds. Larger plats were sprayed with a machine owned by the nursery which consisted of a double-acting hand pump capable of 100 pounds pressure and a 50-gallon galvanized tank set on a truck narrow enough to allow it to pass between two rows of trees. "Set nozzles" on an arrangement of pipes at the rear of this outfit were used, the nozzles

being so placed that it was possible to spray the undersides of the leaves of two rows of trees from both sides. It was necessary to use eight nozzles on this machine and consequently the pressure was greatly reduced.

Table XX indicates the results obtained with the compressed-air sprayer against the first-brood nymphs:

TABLE XX.—*Spraying experiments against the first-brood nymphs of the apple leaf-hopper, West Chester, Pa., 1916.*

| Plat No. | Spray material. | Strength. | Date of application. | Number of trees treated. | Nymphs killed. |
|---|---|---|---|---|---|
| | | | | | *Per cent.* |
| 1 | 40 per cent nicotin sulphate and fish-oil soap | 1–1,000 2–50 | June 12 | 300 | 99 |
| 2 | 40 per cent nicotin sulphate and fish-oil soap | 1–1,400 2–50 | ...do.... | 300 | 98 |
| 3 | 40 per cent nicotin sulphate | 1–1,400 | ...do.... | 300 | 94 |
| 4 | 40 per cent nicotin sulphate lime-sulphur solution | 1–1,500 $1\frac{1}{2}$–50 | ...do.... | 300 | 99 |
| 5 | Check; unsprayed | | | | 0 |

It will be noted that good results were obtained on all plats of this experiment from the use of 40 per cent nicotin sulphate, though slightly better control was obtained when soap was added as a spreader.

The hand-power outfit with "set nozzles" was used in an experiment on several thousand 2-year-old trees which were heavily infested with first-brood nymphs.

The results are shown in Table XXIV.

TABLE XXI.—*Spraying experiments against the first-brood nymphs of the apple leaf-hopper, West Chester, Pa., 1916.*

| Plat No. | Spray material. | Strength. | Date of application. | Number trees treated. | Nymphs killed. |
|---|---|---|---|---|---|
| | | | | | *Per cent.* |
| 1 | 40 per cent nicotin sulphate | 1–1,400 | June 15 | 4,000 | 92 |
| 2 | .....do | 1–1,500 | ...do..... | 10,000 | 91 |
| 3 | .....do | 1–1,600 | ...do..... | 4,000 | 89 |
| 4 | 40 per cent nicotin sulphate and fish-oil soap | 1–1,500 2–50 | June 16 | 13,000 | 97 |
| 5 | Fish-oil soap | 1–8 | ....do.... | 4,000 | 50 |
| 6 | Kerosene emulsion | 5 per cent | ....do.... | 4,000 | 45 |
| 7 | Check, unsprayed | | | | 0 |

As will be noted, the best results in Table XXI were obtained on plat 4 where 40 per cent nicotin sulphate at a strength of 1–1,500 was combined with soap. The nicotin solution when used alone proved a little less effective than when the soap was added to the mixture as shown in plats 1, 2, and 3. A potash fish-oil soap solution at a strength of 1 pound of soap to 8 gallons of water (plat 5) gave poor results and was but little more valuable than a 5 per cent kerosene emulsion which was tried on plat 6.

During the spray application with "set nozzles" it was noted that the terminals of an occasional tree were missed by the spray. One reason for this was that the machine was top heavy and easily jolted when passing over a rough or stony place, and this resulted in the spray material being sent over the top of a tree. Furthermore, a few trees would outgrow the remainder of the trees in a row, so the spray material from the "set nozzles" would not reach the terminals of such trees. Nevertheless, sufficiently good results were obtained with the "set nozzles" to warrant their use.

#### TREATMENT FOR THE SECOND BROOD.

An attempt was made to destroy the second-brood nymphs by spraying and dipping upon trees which had received no treatment against the first brood. On the date of this experiment, July 18, the terminal leaves were so badly curled that the nymphs were well protected from the action of the spray. Four plats of about 700 trees were sprayed with a compressed-air sprayer, using 40 per cent nicotin sulphate at various strengths from 1–800 to 1–1,500 with soap added. The counts showed that only 2 per cent of the nymphs were killed on the best plats.

The dipping work was done with large shallow pans specially constructed for dipping leafhoppers and aphids on young nursery trees. The tops of the trees were thoroughly immersed in the pans of spray material. The same number of plats and the same insecticides that were used in the spray treatment above were tried in the dipping experiments. The results obtained by dipping were about the same as the spraying results, less than 2 per cent of the nymphs being killed.

Since such poor results were secured from spraying experiments against the second brood no effort was made to spray the third-brood nymphs, for at the time of the presence of the latter on unsprayed trees the terminals are even further curled and inaccessible to a spray liquid.

#### METHODS AND TIME OF APPLICATION.

Attempts to control the winged adults of leafhoppers by spraying have always proved futile because of the agility of movement of the full-grown insects and because of their immunity to the action of a spray liquid at this stage. This has been demonstrated by previous investigators in the case of the apple leafhopper as well as in the case of other leafhoppers of economic importance.

A spray treatment to be effective must be applied when the insects are in the nymphal stages. The proper time to spray against the apple leafhopper is at the time when a large number of the first-brood nymphs have attained the third stage of development. For the

seasons of 1915 and 1916 at West Chester, Pa., this date was between June 10 and June 20. It is not safe to delay the application until the end of the nymphal period, since by that time the insects will have produced sufficient injury to cause the tender terminal leaves to curl, and the result is that the nymphs on the curled leaves will be protected against the spray.

The nymphs feed on the undersides of the terminal leaves during the entire nymphal period, so the spray material must be directed in such a manner as to wet the underside of the leaves thoroughly. Special care must be taken to see that the foliage of the upper half of the trees and especially the terminals are well sprayed. If a machine with "set nozzles" is used, the lower nozzles should be placed at an angle that will insure a thorough spraying of the lower surfaces of the leaves.

### TREATMENT FOR THE ROSE LEAFHOPPER.

The injury caused by the rose leafhopper on nursery apple trees is seldom serious enough to warrant a special spray application. This species confines its attack to the undersides of the leaves of the lower half of the trees and the injury is characterized by mottled white or yellowish spots on the foliage. As a result of continued feeding some defoliation takes place which reduces the vitality of the trees slightly.

Whenever necessary, this species can be controlled by one spray application of a tobacco insecticide against the first-brood nymphs. A spraying of ¼ pint of 40 per cent nicotin sulphate to each 50 gallons of water with the addition of 2 pounds of soap, made at the time when the maximum number of nymphs are present on the foliage, will give satisfactory results. The most effective time to make this application is when the greatest number of nymphs have reached the third stage, which is three to four weeks earlier than the date for the spraying against the first-brood nymphs of the apple leafhopper. For southeastern Pennsylvania the correct time for spraying the rose leafhopper during the seasons of 1915 and 1916 was from May 15 to May 25.

### RECOMMENDATIONS.

The apple leafhopper can be controlled by spraying against the first-brood nymphs with a tobacco insecticide. A 40-per cent nicotin sulphate solution at the rate of 1–1,500 to which 2 pounds of soap is added to each 50 gallons will so reduce their numbers that injury to the growth of the trees by the later broods will not be serious. When it is desirable to use lime-sulphur solution with the tobacco insecticide, soap must be omitted to prevent burning. The spray should be directed upward so as to wet the underside of the leaves, and par-

ticular attention should be paid to wetting every terminal leaf thoroughly. The application should be made when the majority of the nymphs are in the third stage, which occurs about three weeks after the first nymphs are found in the terminal leaves.

The rose leafhopper is far less injurious to the foliage of nursery apple stock than the apple leafhopper. Should the infestation by rose leafhoppers be heavy enough to justify spraying, the same remedial treatment recommended for the apple leafhopper can be used, except that the application should be made three or four weeks earlier than the one for the latter insect.

## SUMMARY.

The apple leafhopper, *Empoasca mali*, causes serious injury to apple nursery stock by extracting the plant juices from the terminal leaves; as a consequence the leaves curl, become undersized, and fail to function normally, thereby retarding the growth of the trees. The injury is produced by the feeding of both nymphs and adults. In southern Pennsylvania this species is three-brooded and hibernates only in the adult stage. Eggs are laid within the leaf tissue on the underside of the leaves. This leafhopper is widely distributed over the United States and attacks a great variety of host plants.

In literature the above species has been confused with another leafhopper which attacks the foliage of nursery apple trees, namely, the rose leafhopper, *Empoa rosae*. The latter insect is two-brooded and winter is passed in the egg stage. Winter eggs are deposited under the bark of apple trees. These eggs hatch about a month earlier in the spring than eggs deposited by overwintered females of the former species.

The rose leafhopper may be distinguished from the apple leafhopper by its lighter color and by the absence of the six or eight white spots present on the frontal margin of the pronotum of the latter species. Differentiation between the nymphs of the two species is more difficult. The distinct types of injury produced by the two insects, however, is a ready means of distinguishing them. The rose leafhopper feeds on the lower leaves and produces white or yellow spots on them while the other species attacks the terminal leaves, curls them, and stunts the growth of the trees.

Parasites seem to play a far more important rôle in reducing the numbers of the rose leafhopper than they do in reducing the numbers of the more injurious apple leafhopper. Larvæ of dryinid parasites are quite common on the adults of the former while only rarely have they been found attacking the latter. *Anagrus epos* Girault and *Anagrus armatus* Ashm. var. *nigriventris* Girault, parasites of the winter egg of the rose leafhopper, help considerably in checking the num-

bers of this species. No parasites have been reared from eggs of the apple leafhopper.

A single spraying with 40 per cent nicotin sulphate at the rate of 1–1,500 combined with soap will so materially check an infestation by the apple leafhopper when applied against the first-brood nymphs that injury caused later by those that escape will be of little consequence. The same treatment made three or four weeks earlier is effective against the rose leafhopper, though this species is seldom injurious enough to justify a special application.

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