THE STRAWBERRY ROOT LOUSE IN TENNESSEE

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INTRODUCTION

In Tennessee, strawberries are classed as nursery stock and before they can be shipped an inspection is required for injurious insects, particularly for the strawberry root louse (Aphis forbesi Weed). Since no extended study of this insect in Tennessee had ever been made and since little is known concerning it in other States, except in Delaware, it seemed desirable to make a study of its habits and to determine if possible its economic importance. When one considers the vast quantities of strawberries grown in Tennessee, which is the largest strawberry-producing State in the Union, and the time consumed each year inspecting them, the need of a more definite knowledge of the economic importance of this insect becomes apparent.

GEOGRAPHIC RANGE

The strawberry root louse is a native insect confined to eastern North America, and has been reported injurious in Illinois, Ohio, Maryland, Tennessee, and Delaware, although it has recently been learned through correspondence that it is no longer so considered in the last-named State. In Tennessee it is present wherever strawberries are grown.

HOST PLANTS

The cultivated strawberry, Fragaria sp. appears to be the only host of Aphis forbesi Weed. Repeated efforts have been made to find it on other plants, but without success. Often the roots of various weeds are infested with lice very similar in appearance to the strawberry root louse, but close examination reveals them to be other species, usually the corn root louse, Aphis maidiradicis.

ECONOMIC IMPORTANCE

Plant lice in general are of great economic importance, yet there are many species that do little or no harm. To obtain exact data in regard to injury caused by Aphis forbesi Weed, experiments were conducted in the field during 1921 and 1922. The vigor of a strawberry plant is indicated by the number of plants and runners which it produces. Plants artificially infested with lice were set out in March and a record was kept of the number of plants and runners produced. The plants used in the control plat were freed from any lice that may have been present by dipping them in a tobacco solution. The control plat was also frequently sprayed with tobacco to guard against infestation. The results obtained for the year 1922 are as follows: Of 12 infested mother plants the maximum number of plants produced by any one was 150, the minimum 12, and the average 47.6. Of 22 control mother plants the individual maximum was 120, the minimum 4, and the average 49.7 plants. The mother plants were set March 28 and the count of plants produced was made September 16, 1922. The difference in the percentage of plants produced by the infested mother plants and the controls was small, and could easily come within the limits of experimental error.

Practically the same results were obtained in 1921. Ladybird beetles often destroyed the lice on the crown of the plant, where they are frequently found. In such cases the plants were artificially reinfested.

To ascertain the general importance of the strawberry root louse a circular letter was sent to all the important strawberry-producing States. Replies from Iowa, Illinois, Ohio, New Jersey, Delaware, North Carolina, Georgia, Florida, Louisiana, Mississippi, and Arkansas indicated that the strawberry root louse was not considered injurious to the strawberry, or that little consideration was given to it. The only State reporting serious injury from this pest was Maryland, where it is considered "highly undesirable" in the light sandy soils, although no data were given. The strawberry soils of Ten-

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nessee are mostly loams or silt loams, which may be one reason why the insect is less injurious in this State.

LIFE HISTORY

Unlike some other species of plant lice, the strawberry root louse spends its entire life cycle upon the strawberry, migrating only to other strawberry fields.

THE EGG

The insect passes the winter in the egg stage upon the pedicels of the leaves (pl. 1, c), although eggs are sometimes laid on the underside of the leaves. In 1921, at Knoxville, Tenn., hatching began on February 15, and in 1922 on February 22; hatching continues for about a month.

FIRST INSTAR (PL. 2, G)

Color characters: Upon hatching the new-born nymphs are pale green in color, with legs, antennae, and cornicles whitish. After a few hours the general coloration becomes greenish; head lighter, with two chitinized areas on either side of the median line; eyes reddish; antennae pale yellow, darker apically; tip of beak dusky; legs pale yellow; tarsi dusky; cornicles pale, darker at the tip.

Morphological characters: Body rectangular, flattened; antennae and legs robust as compared with the rest of the body; antennae four-jointed, with a sensorium present at the distal end of the third joint and at the proximal end of the flagellum of the fourth joint; cornicles short, about as broad as long.

Measurements: Length, 0.52 to 0.60 mm.; width, 0.28 to 0.30 mm.; antennae, 0.26 mm. (pl. 3, J); segment No. 1, 0.03 mm.; segment No. 2, 0.03 mm.; segment No. 3, 0.08 mm.; segment No. 4, 0.12 mm.; cornicles (pl. 3, K), length, 0.03 mm.; width, 0.03 mm.

SECOND INSTAR

This stage does not differ in general coloration from that of the first stage. The body becomes ovate in form and the antennae five-segmented. The cornicles also become more elongate, being about twice as long as wide.

Measurements: Length, 0.82 to 0.92 mm.; width, 0.40 to 0.44 mm.; antennae, 0.31 mm.; segment No. 1, 0.03 mm.; segment No. 2, 0.03 mm.; segment No. 3, 0.06 mm.; segment No. 4, 0.04 mm.; segment No. 5, 0.15 mm.; cornicles, length, 0.05 mm.

STEM-MOTHER

After passing through five instars the stem-mother becomes mature in two to three weeks, depending upon the temperature. In 1921 stem-mothers were full grown as early as March 8. Upon maturity, often only a few hours after the last molt, they give birth to living young. In a study of the reproductive capacity of the stem-mothers, it was found that they were capable of giving birth to an average of two young per day for a period of 20 to 28 days. The highest number of young produced in one day was six.

The initial feeding of the young stem-mothers takes place where they hatch, but after a short time they find their way to the tenderest leaves just coming out of the crown. Here they insert their beaks and suck the sap.

Color characters: The general coloring of the stem-mother is bluish-green, head greenish, with anterior portion lighter. Eyes dark red; antennae with segments 1, 2, and basal portion of 3, pale yellow; remainder of segments dark brown; beak yellowish, tip black, reaching to base of third pair of legs; legs yellowish; tarsi dusky; cornicles yellowish-brown, darker at tip; cauda yellowish brown, clothed with whitish hairs; posterior border of terminal abdominal segments, with a whitish pulverulent stripe; genital plate greenish-yellow; anal plate dark green.

Morphological characters: Body ovate, tending to pear-shape; antennae six-jointed, with segments 3 and 4 not differentiated; thorax with a prothoracic tubercle on each side; cornicles tubular, tapering distally.

Measurements: Length, 1.3 to 1.5 mm.; width, 0.74 to 0.78 mm.; antennae, segment No. 1, 0.05 mm.; segment No. 2, 0.04 mm.; segment No. 3, 0.22 to 0.24 mm.; segment No. 4, 0.; segment No. 5, 0.10 to 0.11 mm.; segment No. 6, 0.06 to 0.18 to 0.20 mm.; cornicles, length, 0.19 to 0.21 mm.

EXPLANATORY LEGEND FOR PLATE 1

A.—Mother plant with 18 runners. Photograph made in midsummer from plot artificially infested with *Aphis forbesi*, showing vigorous condition

B.—Oviparous females of *Aphis forbesi* clustered on young tender leaf

C.—Egg of *Aphis forbesi* on pedicel of strawberry leaf

D.—Mound built by *Pheidole vinelandica* around pedicel of strawberry leaf protecting *Aphis forbesi*

E.—*Paragus tibialis*: Female, parasite on *Aphis forbesi*

F.—*Paragus tibialis*: Pupa

G.—*Paragus tibialis*: Larva
The Strawberry Root Louse in Tennessee

Plate 1

(For explanatory legend see p. 412)
WINGED VIVIPAROUS FEMALE (PL. 2, A)

Color characters: The general coloration is black. Head dark brown; eyes dark red, ocelli yellowish; antennae varying from pale yellow to dusky; beak yellowish, darker toward the tip; prothorax black, with anterior and posterior margins greenish, mesothorax and metathorax shining black, suffused with brown on the sides, legs yellowish; tarsi darker; abdomen greenish, with lateral margins of segments 1 to 5 with spotted black; cornicles brownish; cauda and genital plate green; anal plate black.

Morphological characters: Antennae six jointed, joints 3 and 4 sometimes indistinct, third segment with three sensoria; prothorax with two lateral tubercles; abdomen with a very small lateral tubercle; cornicles long, tubular, and flanged at the tip.

Measurements: Length, 1.3 to 1.8 mm., width, 0.7 to 0.8 mm., antennae, length, 0.9 to 1.1 mm.; segment No. 1, 0.05 mm.; segment No. 2, 0.05 mm.; segment No. 3, 0.19 to 0.24 mm.; segment No. 4, 0.12 to 0.18 mm.; segment No. 5, 0.13 to 0.16 mm.; segment No. 6, 0.35 to 0.40 mm.; cornicles, length, 0.2 to 0.22 mm.

OVIPAROUS FEMALE (PL. 2, C AND E)

Color characters: General coloring yellowish-green; head yellowish-brown, sometimes greenish on posterior half; antennae with segments 1, 2, and basal portion of 3 pale yellow, remainder of segments darker; eyes dark red; beak greenish at base, pale yellow at middle, and dark at tip; legs pale yellow, tarsi darker; cornicles brownish, darker at tip; cauda dusky, clothed with whitish hairs; margins of abdomen greenish, with center of dorsum yellowish when the abdomen is distended with eggs; posterior abdominal segments more or less covered with a whitish pulverulence; genital plate greenish, with two circular yellowish areas on either side; anal plate dark green.

Morphological characters: The body is more elongate and narrower than in apterous viviparous female, tapering posteriorly. Antennae (pl. 3, H) six-jointed as in viviparous female; thorax with lateral tubercles on prothorax; hind tibia (pl. 3, I) with about eight sensoria, not at all swollen, and hardly to be distinguished from the other forms; abdomen with a tubercle on either side; cornicles short, tubular, and flanged at the tip (pl. 3, E); genital plate more rounded than in the apterous viviparous female.

Measurements: Length, 1.2 to 1.5 mm.; width, 0.6 to 0.7 mm.; antennae, segment No. 1, 0.05 mm.; segment No. 2, 0.05 mm.; segment No. 3, 0.28 mm.; segment No. 4, 0; segment No. 5, 0.12 mm.; segment No. 6, 0.10 to 0.24 mm.; cornicles: length, 0.12 mm.

MALE (PL. 2, D AND F)

Color characters: General coloration brownish-yellow, mixed with green; antennae brownish-yellow, sensoria darker; head brownish, darker on posterior half; eyes dark brown, beak pale yellow, tip brown, thorax greenish; legs yellowish, with coxae, trochanters, and tarsi darker; cornicles brownish, darker at the tip; abdomen brownish spotted with pale yellow in the center, posterior segments dusky; cauda dusky, clothed with whitish hairs; genital plate brownish; anal plate black.

Morphological characters: Body short and broad; antennae about as long as the width of the body, six-jointed, with five to seven sensoria on segment 3, and one sensoria on each of segments 5 and 6; prothorax with small tubercles; abdomen with lateral margins flattened, a lateral tubercle on each side; cornicles short, tubular, slightly curved, and flanged at the tip; genital plate bears two claspers clothed with spines and hairs.

Measurements: Length, 1 mm.; width, 0.64 mm.; antennae, segment No. 1, 0.04 mm.; segment No. 2, 0.04 mm.; segment No. 3, 0.20 mm.; segment No. 4, 0; segment No. 5, 0.088 mm.; segment No. 6, 0.058+ to 0.18 mm.; cornicles, length, 0.12 mm.

SPRING FORMS

The majority of the second generation of the insect becomes wingless viviparous females (pl. 2, B, and pl. 3, F, G), although some winged ones are often present and distribute the species to other strawberry plants or beds. The young of the second generation are pale yellowish-green in color, in contrast to the dark green of the stemmothers. The second and succeeding generations are usually found feeding on the pedicels of the young tender leaves, but are often deeply imbedded in the crown of the plant. They are sometimes located on the roots of the plants, but in Tennessee this is rare. Large numbers of plants were pulled to determine the location of the lice, and, except in a few cases, they were present on the pedicels of the young leaves. A generation of lice is produced about every 14 days throughout the summer, with winged ones appearing in each generation after the first.
The Strawberry Root Louse in Tennessee

Plate 2

A.—Winged viviparous female
B.—Wingless viviparous female
C.—Oviparous female
D.—Male
E.—Posterior end of venter of oviparous female
F.—Posterior end of venter of male
G.—First instar of stem-mother
The Strawberry Root Louse in Tennessee

Plate 3

(For explanatory legend see p. 447)
In midsummer it is difficult to find any lice at all, owing to the activities of their natural enemies. Both young and mature forms were present on the rootlets as early as April 11.

THE TRUE SEXES

The true males and females make their appearance in Tennessee late in October, and may be found on the plants until February, when the eggs are ready to hatch. After maturing, the females deposit eggs, which carry the species over the winter. Although viviparous females may be present on the plants as late as December, they invariably die and do not assist in the reproduction of the species.

The males are small, wingless, and comparatively few in number. On one leaf pedicel there were counted 2 males and 22 oviparous females. The oviparous females can be readily recognized by their elongate appearance and lighter color, caused by yellowish eggs showing through the chitin. In 1922 the first eggs were laid on November 9, although active egg laying does not begin until December. The eggs when first deposited are orange colored, and it is not until several days later that the characteristic shiny black color is assumed. The number of eggs deposited by a single female varies from four to eight.

FACTORS WHICH INFLUENCE THE APPEARANCE OF THE SEXES

With remarkably few exceptions, the true sexes in plant lice, including *Aphis forbesi*, make their appearance in the North Temperate Zone in the fall of the year and pass the winter in the egg stage. In the more southern localities plant lice generally reproduce throughout the year without the appearance of true sexes or eggs. Therefore, it is natural to conclude that the factor stimulating the formation of true sexes must be temperature; and such was assumed to be the case.

PRODUCTION OF TRUE SEXES AND ITS RELATION TO THE SHORT DAYS OF FALL

One of the familiar phenomena of the Temperate Zone in the autumn is the shortening of the length of day. To create an artificial short day the potted plants used in the experiments were placed out of doors in a dark, ventilated chamber at 5 p. m. and kept there until 9.30 the next morning, when they were removed and placed in the light. The plants and plant lice were thus subjected each day to seven and one-half hours of light exposure. Any response on the part of the insects could hardly be attributed to temperature, since the temperature inside was but 2° to 3° F. higher than that outside. Single potted plants were also darkened by having inverted over them a larger pot or box.

In 1922 the plant with lice was subjected to a short day, beginning May 23. The first males and oviparous females were observed to make their appearance on September 18. Eggs were deposited on September 22, this being about seven weeks earlier than the first eggs are deposited in the field.

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**EXPLANATORY LEGEND FOR PLATE 3**

A. — *Diaperetus fuscicornis*
B. — *Paragus tibialis*: Egg
C. — *Paragus tibialis*: Egg under high magnification showing sculpturing
D. — *Paragus tibialis*: Caudal appendage
E. — *Aphis forbesi*: Cornicle of oviparous female
F. — *Aphis forbesi*: Cornicle of wingless viviparous female
G. — *Aphis forbesi*: Antenna of wingless viviparous female
H. — *Aphis forbesi*: Antenna of oviparous female.
I. — *Aphis forbesi*: Hind tibia of oviparous female
J. — *Aphis forbesi*: Antenna of first instar stem-mother
K. — *Aphis forbesi*: Cornicle of first instar stem-mother
In 1923 the plants were given a short day, beginning February 23, at which time the eggs were already hatching. By May 7 males and oviparous females had made their appearance, and the first eggs were deposited on May 22. In another experiment, beginning March 21, a plant with lice in the second generation was subjected to a short day, and by May 12 the oviparous females had made their appearance.

THE TRUE SEXES AS INFLUENCED BY A LONG DAY

According to the above experiments the production of the true sexes appears to be governed by the short days of the fall. How, then, would a daily light exposure of 15 hours or more act, and would the production of viviparous forms continue? To determine this point some strawberry plants infested with lice were placed out of doors September 4 and given 15 hours of daily light exposure by means of a 60-watt electric light, which hung about 2 feet from the plants. At this distance the light did not raise the temperature of the air around the plants, as shown by several tests. A control plant was placed inside the laboratory, next to the window at the same time. On October 6 viviparous females made their appearance on the control plant, but were not yet present on the plants given the long day. On November 5 eggs were found on the control. When examined on December 22, viviparous forms only were still present out of doors on the plants receiving the long exposure. However, the sexes did make their first appearance on January 4, 1924. This would indicate that a long day may successfully inhibit the formation of the true sexes, provided a certain temperature level is maintained. The first 15 days of December averaged 40° F. and it is very likely that it was in this period that sex formation was initiated. In addition to a certain temperature level, possibly minimum temperatures may be factors. A minimum temperature of 28° on November 9 and 10, and 20° on December 15 was recorded. Garner and Allard 2 have found that biennials will behave as annuals when subjected to a combination of long days and a lower temperature level. Lower temperatures alone would not accomplish this result.

It should be noted that the strawberry plants bearing aphids were given a long daily light exposure beginning September 4. The experiment was started early enough to insure if possible against the production of the sexes. In 1922, strawberry plants were given a long daily exposure beginning October 12, and a few sexed individuals appeared two weeks later. This shows that once the tendency toward true sex production is initiated, it can not be done away with. However, in the early part of September that tendency is still absent in Aphis forbesi in Tennessee.

RELATION OF ANTS TO THE APHIS

Sanderson 3 records that the ant, Lasius alienus, attends the strawberry root louse in Delaware and carries it down to the roots of the plants, especially where the soil is sandy. In Tennessee various species of ants have been observed to care for the lice, but the species that is by far mostly commonly found is the little brown ant, Pheidole vinelandica, as determined by W. M. Wheeler. This species may be found about strawberry plants in March and up to January. Its method of tending the lice in order to obtain honeydew is interesting. Since the lice are most often clustered on the pedicels of the small, tender leaves, the ants protect them by building small craterlike mounds of dirt about the crown, so that the pedicels of the young leaves may be entirely covered and concealed from view, as shown in Plate 1, D. These little craters are often 2½ inches high, and sometimes completely cover the crown of the plant. In such cases lice may be found feeding on the crown of the strawberry.

NATURAL ENEMIES

The strawberry root louse will sometimes increase in numbers to such an extent that it becomes noticeable, but in most cases its natural enemies keep it in check. Several different species of these were bred, among them a syrphid that had never been reported as preying upon the strawberry root louse, and an undetermined chalcid. Parasites were bred as late as December 14 and as early as May 14. Ladybird beetles, such as Hippodamia convergens and Coccinella novemnotata, were frequently found upon the root louse, as well as a larva

of one of the Chrysopidae. Sanderson records several hymenopterous parasites, among which are Lysiphlebus myzi Ashm., L. salicaphidis Ashm., Lygocerus stigmatus Sag., and Adialatus densleonis Ashm. A louse attacked by parasites appears plump and greenish in color. As the parasite grows the body of the louse becomes much distended, and upon maturity nothing is left of the host except the straw-colored chitinous envelope.

**DIARETUS FUSCICORNIS ASHM.**

This little braconid (pl. 3, A) as determined by A. B. Gahan, was frequently bred from lice clustered on the pedicels of the leaves, and undoubtedly helps to keep the lice in check. In color, it is shining black, legs yellowish, mixed with brown. Antennae of male 15-jointed, of female 13-jointed. Length 1.6 mm.

**PARAGUS TIBIALIS**

This syrphid (pl. 1, E, F, G and pl. 3, B, C, D) appears to be the most constant and efficient enemy of the strawberry root louse in Tennessee. The larvae were found in the field as early as April 18. A larva was observed to devour seven lice in five minutes in the laboratory. Larvae collected on May 20 pupated May 22, and the adults emerged May 29. The puparium is inconspicuous on the under side of the leaves, and rather resembles a piece of dirt.

**Egg.**—Chalk-white in color. In outline, subcylindrical and ovate; truncated at the narrow end and rounded at the other. The surface of the egg is covered with very fine microscopic elevations arranged in lines, which under high magnification are seen to possess projecting arms, as shown in pl. 3, C. Length, 1 mm.; width, 0.40 mm.

**Larva.**—General coloring pale yellow, mixed with patches of brown; posterior respiratory appendages dark brown at base, yellowish on apical third. Dorsal spiracular spine brownish. Surface of skin covered with minute, wartlike elevations. The spines on segment 4 appear equal. Beyond this segment the dorso-lateral spines are the longest, the dorsal spines small. Dorsal spiracular spine large, concave lateral, bifurcate. Length, 6 to 7 mm. Length of posterior respiratory appendage, 0.46 mm.

**Adult.**—General coloring black, frequently reddish on the abdomen. Both male and female with a median black band on the face. Length, 3 to 5 mm.

**SUMMARY**

Since strawberries are classed as nursery stock in some States and required to be inspected for the strawberry root louse, *Aphis forbesi* Weed, it becomes necessary to determine more exactly its economic importance. Observation and experiments since 1919 show that *Aphis forbesi* is present in all the strawberry-growing areas of Tennessee and that it can not be classed as highly injurious in that State. It is not a leaf curler and apparently injects no toxin into the host plant. Plants were artificially infested with the root louse and kept so throughout the summer to determine the effects on the production of runners. These plants each produced an average of 47.6 plants as compared with 49.7 plants produced by the controls.

*Aphis forbesi* passes the winter in the egg stage on the pedicels of the leaves. Hatching begins about February 15 and continues for about a month. Reproduction continues viviparously throughout the summer and as late as November. In Tennessee the lice remain mostly on the pedicels of the leaves and around the crown of the plant. Only rarely are they found on the roots. The ant, *Pheidole vinelandica*, is most commonly associated with *Aphis forbesi*.

The true sexes first make their appearance in October and may be found on the plants until February.

In a study of the factors influencing the production of the true sexes in *A. forbesi*, it was found that the relative length of exposure to daily light appears to be an important factor. By giving a daily short exposure of seven and one-half hours, beginning February 23, the sexes made their appearance on May 7. Eggs were deposited on May 22.

During the fall months of 1923 when the plants were given a long daily light exposure of 15 hours out of doors, the aphids continued to reproduce viviparously as late as January 4, 1924, when the first true sexes made their appearance.

**The strawberry root louse has many natural enemies, among the most important of which is the little syrphid known as *Paragus tibialis*. Other natural enemies include several species of Braconidae, the most common being Diaretus fuscicornis. Several Coccinellidae and Chrysopidae may frequently be found preying on the lice.**
