

THE GENUS EMPOASCA IN NORTH AMERICA

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INTRODUCTION

While the writer was connected with the Iowa Agricultural Experiment Station the potato leafhopper (*Empoasca mali*) appeared in immense numbers in the Upper Mississippi Valley. Investigations were carried on during the summers of 1919, 1920 and 1921 at Ames, Iowa, to establish definitely the relation of this insect to the disease it transmits, commonly called tipburn or hopperburn of potatoes, which was causing severe damage to the potato crop, and if possible devise means for its control. The difficulty experienced in separating closely related species of *Empoasca*, which had been confused by former investigators, led to the desire to trace the systematic relationships of this group in the hope of establishing a more satisfactory means of identification, which has resulted in a systematic revision of the genus. The need of more biological data, especially of those species which are of economic importance, prompted a detailed study of the life histories of the potato leafhopper (*Empoasca mali*) and its closely related species, the apple leafhopper (*E. unicolor*) to remove the confusion that has until recently existed in the economic literature regarding these forms. A detailed life history of the latter species is here presented with a summary of the writer's work on the life history of *mali*.

For the systematic literature the reader is referred to Van Duzee's Catalogue of the Hemiptera of America north of Mexico (1917). Changes in synonymy and additions have been included in this paper together with a bibliography of the more important economic literature. The writer has confined his treatment of the genus to species found in the United States and Canada. The location of type material actually observed by the writer is indicated after each description. The types of species described as new are deposited in the Ohio State University collection. The life history studies have extended over a number of years of field work, but the final summary and all the systematic work was done in the Entomological Laboratory of the Ohio State University.

ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation to the many who have assisted him in this work. Especially is he indebted to Professor Herbert Osborn for the use of his private collection and library and for suggestions and encouragement throughout the preparation of this dissertation and also to the following persons who have kindly assisted him during this study; to Dr. D. M. DeLong, for the loan of his excellent collection of *Empoasca* from Tennessee; to Mr. W. L. McAtee, for courtesies extended while working in the National Museum; to Dr. E. D. Ball, for the privilege of examining the types of *minuenda* and records; to Dr. C. J. Drake, for permission of using Plate I; to Professor J. G. Sanders for records of *Empoasca* in his collection; and to Dr. F. A. Fenton, for his kindness in permitting the writer to use certain data which were obtained in connection with our studies of the life history of the potato leafhopper.

ECONOMIC IMPORTANCE OF *EMPOASCA*

For many years this genus has been recognized as having species of economic importance, but it was not until recently that the full significance of these pests was brought to the attention of entomologists. *Empoasca mali* has long been known as an apple pest and was commonly called the apple leafhopper, although it was early recognized (Osborn, 1896) as injurious to potatoes. Webster (1910) was the first to make an extensive study of this species as a pest of potatoes, but it was not until the work of Ball (1918 a, b, c), that the importance of this species as a potato insect was established and its name was changed to the potato leafhopper. By a series of carefully conducted field experiments Ball showed that when these leafhoppers were caged on potato vines they produced a distinct leafburn, commonly called tipburn, which is due to the activities of the nymphs and adults.

Experiments conducted at Ames, Iowa, show conclusively that the disease never occurs unless adults or nymphs of *mali* are present (Fenton, 1921; Fenton and Hartzell, 1922; Fenton and Ressler, 1922). When plants were caged so that the leafhoppers were excluded they developed normally, although the remaining plants in the field were affected with hopperburn. The vigorous growth of the caged plants was not due to shading, as several types of cages were used and the results can be accounted for in no other way than due to the exclusion of insects in general and *mali* in particular. When several hundred adults were introduced

into a cage hopperburn occurred. On the other hand, if a few adults were introduced and allowed to lay eggs in the leaves, hopperburn did not appear until the eggs hatched and the nymphs began feeding on the leaves. Differences in types of soil, light intensity, temperature and humidity have no effect on the production of hopperburn except as they influence the nymphs or adults (Fenton and Ressler, 1922).

The work of Parrott and Olmstead (1920) in New York, of Dudley and Wilson (1921) in Wisconsin, of Beyer (1922 a, b) in Florida, and Eyer (1922) in Pennsylvania confirm in the main Ball's observations.

A series of artificial mutilation and inoculation experiments were conducted by Fenton and Ressler (1922) to discover whether hopperburn is due to mechanical injury of the leaf tissue or to a toxic principle emitted by the insect. They found that artificial mutilation did not produce injury comparable with hopperburn. Hypodermic injections of potato leaves with solutions made by macerating nymphs or adults in water in some instances gave positive results, but the lesions in nearly every case were localized.

There are differences of opinion as to the cause of hopperburn. It is usually considered to be due to a virus transmitted by the potato leafhopper, but thus far no organism has been isolated that has been considered the causal agent of the disease. That the potato leafhopper is in some way responsible for the transmission of the disease is now generally accepted. Not all leafburn, however, found on potato leaves is caused by the potato leafhopper, and considerable confusion has resulted because of the failure of different authors to distinguish between these various leaf disorders. Hopperburn always begins at the margin of the leaf, usually at the tip, and the burning follows inward along the veins. The first indication of this disease is usually a triangular burned area at the tip of the leaf which extends for some distance along the midrib. Other more or less wedge-shaped burned areas follow along the veinlets near the margin of the leaf and finally the entire margin turns brown and curls up.

Different varieties of potatoes show differing susceptibility to the disease. The Triumph is probably the most seriously affected while Rural New Yorker probably occupies the first place among resistant varieties.

Fluke (1919) found that the potato leafhopper is repelled by bordeaux mixture. Dudley (1920), Parks and Clayton (1921), Eyer (1921), and Fenton and Hartzell (1922 a) confirmed Fluke's

conclusions and proved the value of bordeaux mixture to be superior to nicotine in the control of this insect. Experiments conducted by Dr. Fenton and the writer (Fenton and Hartzell, 1922 a) proved that bordeaux mixture when applied to potato foliage is toxic to the nymphs and also exercises a repellent action upon the adult females during oviposition.

While *Empoasca mali* is primarily a potato insect, its importance as a pest of apple nursery stock cannot be overlooked. This phase is emphasized in the earlier references (Le Baron, 1853; Forbes, 1884; Washburn, 1908). Ackerman (1919) made an extensive study of this insect as a nursery pest in Pennsylvania. The ability of this insect to disseminate fire-blight (*Bacillus amylovorus* Burrill) has been pointed out by Lathrop (1918). Beyer (1922 a, b) shows the importance of *mali* as a pest of beans in Florida.

Empoasca unicolor has not received general recognition as an apple pest owing to the fact that the species was confused with *mali*. *E. unicolor* occurs almost entirely on apple and has been termed the apple leafhopper as distinguished from the potato leafhopper. The chief injury caused by this species is the spotting of fruit, which will be discussed later.

Empoasca birdii has been reported on apple, hop, walnut, and bean; *tumida* and *alboneura* on plum, but the economic status of these three species has not been definitely determined (Gillette, 1898). The remaining species of *Empoasca* so far as is known are not of economic importance.

Becker (1918) and Lawson (1920) call attention to the fact that *Empoasca mali* will attack man. The writer has had similar experience with this form. The bite causes very little irritation.

GEOGRAPHICAL DISTRIBUTION

The species of *Empoasca* are quite generally distributed throughout North and South America but in the Western Hemisphere it is only those forms that occur north of Mexico that have received more than passing attention. The genus is represented in Europe and forms have been referred to it from South Africa. The most widely distributed species are *mali* and *flavescens* which appear to be also the most abundant in numbers of individuals. The range of *mali*, for example, extends from southern Canada to Argentine Republic, with intervening records from Guatemala, the West Indies and Bolivia. Examples of *flavescens* have been examined from Porto Rico, Guatemala and Bolivia. The Central American forms of these species vary greatly both as to size and

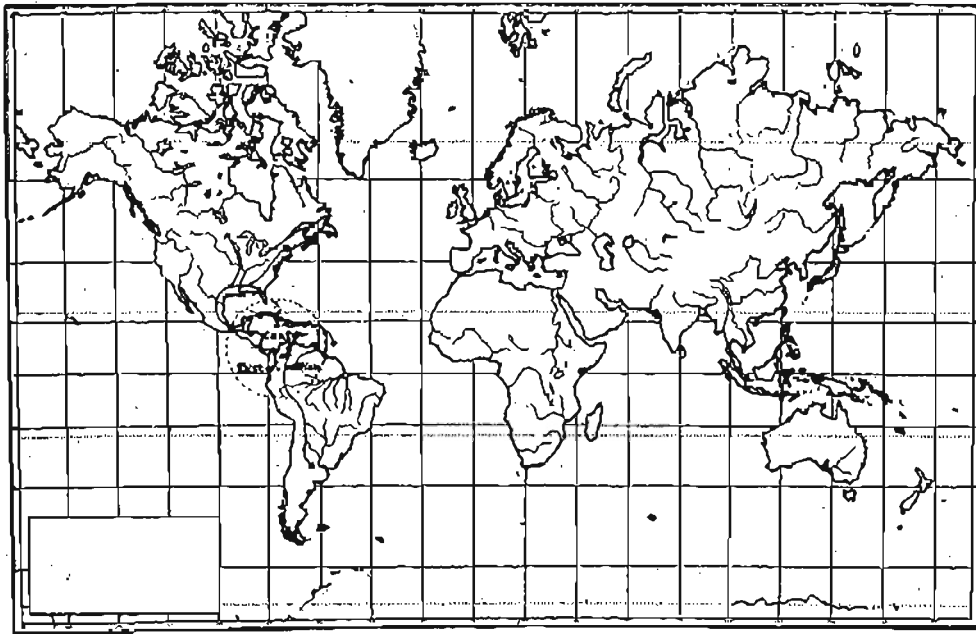


Fig. 1. Map showing the hypothetical dispersal of the ancestral forms of *mali* and *flavescens* from the Central American land mass to North and South America.

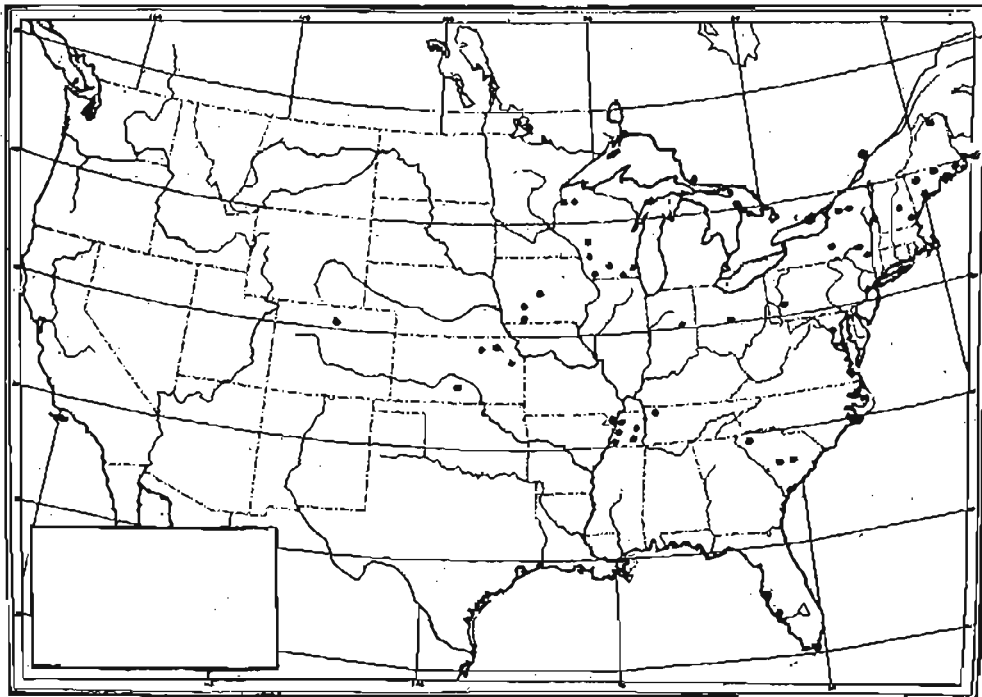


Fig. 2. Map showing the distribution of *Empoasca obtusa*.

markings, which indicates that this region may be the center of distribution of these forms and perhaps for the whole genus. The present state of knowledge of the Cicadellid fauna of tropical regions is too limited to permit generalizations, so we can suggest at most only the possible lines of dissemination and reserve our final judgment in the matter when more data on Neotropical forms have been accumulated. The accompanying map (fig. 1) shows the probable routes of dispersal of the ancestral forms of *mali* and *flavescens*. From the Central American land mass the natural route northward is along the Mexican Coast. The main thoroughfare for animal dispersal has been along the Caribbean and Gulf Coasts. At least those forms that have followed this route have been more successful in establishing themselves, owing no doubt to the fact that the large fertile areas of North America lie in this path. The Appalachian Mountains is the only barrier of any consequence in a northward movement of this kind and it is here probably that the lines diverged, the main one extending its range to the northern part of the Mississippi Valley and the eastern branch following along the Atlantic Coastal Plain.

The presence of representatives of this genus in the West Indies can be explained on geological evidence because of the former land connection between Central America and the Antilles during the Early Eocene epoch (Schuchert). During that period what is now southern Florida was a part of the West Indian land mass, and the spread of the species may have occurred before the Gulf Stream was shunted southward with the elevation of the Gulf Coast region. Southward from the Central American land mass the range would follow naturally along the Andes Mountains to Bolivia and Argentine Republic. Species like *mali* and *flavescens* are aided greatly in extending their range because of the variety of host plants. The presence of members in Europe and South Africa is difficult to explain and probably is due to parallel development or introductions in recent time.

The range of *obtusa* and *trifasciata*, as shown in figures 2 and 3, is confined largely to the eastern portion of the United States. The former species has been reported from Quebec and northern Maine and as far south as Tennessee and the Carolinas and westward to Colorado. The distribution of *trifasciata* is practically the same. It has been reported from the Adirondack Mountains, and as far west as Arizona. In addition to this close parallel in their distribution the two species show taxonomic affinities and their host plants belong to the same bot-

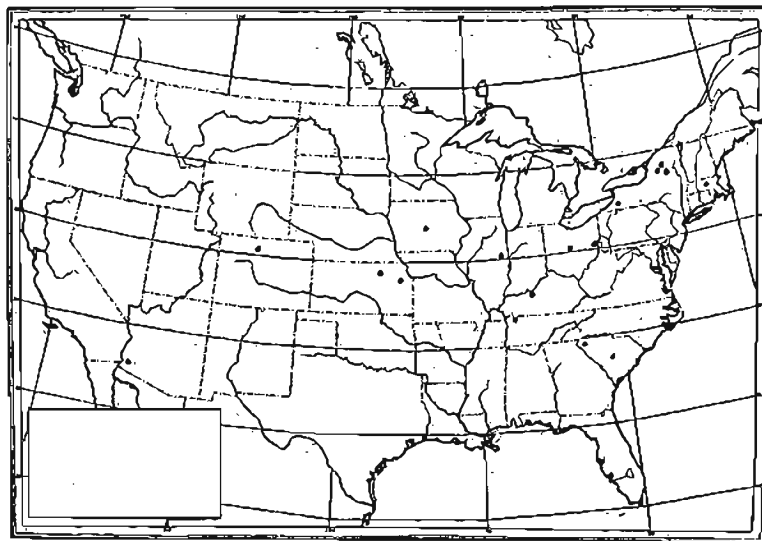


Fig. 3. Map showing the distribution of *Empoasca trifasciata*.

anical family. Willow is the favorite host of *obtusa* and cottonwood of *trifasciata*.

Both *atrolabes* and *smaragdula* show similarities in range to the two species just mentioned in the preceding paragraph. The northern and western limits of *atrolabes* are identical with those of *obtusa* while southward the species has not been reported beyond the Ohio. On the other hand *smaragdula* reaches its northern limit in Maine and occurs as far south as Tennessee and west to California.

Among the economic species *mali* is found practically throughout the United States and southern Canada east of the Rocky Mountains, reaching its greatest abundance in the northern part of the Mississippi Valley. *Empoasca unicolor* is more limited in its southern range than *mali* but covers a wider territory to the westward. The species occurs from Quebec to Florida to western Oregon. Its restriction to one or two closely allied hosts has a tendency to limit both its relative abundance and its distribution. In a similar manner *coccinea*, which feeds on pine exclusively, is concurrent in distribution with its host.

The remaining species of *Empoasca* have not been sufficiently studied to indicate much more than their general distribution and relative abundance. When more is known about these forms the range of some probably will be much greater than we have indicated. Of these *viridescens* appears to be the most widely dis-

tributed, occurring from New York to Georgia and westward to Oregon and California. The few records that are known of *incisa* indicate that it is also a widely distributed species although not so well represented in numbers of individuals. It has been reported from New England, South Dakota and Colorado. The distribution of *pergandei* is parallel, except that it has not been reported from South Dakota.

Among the forms that have been collected from a given region are *unica*, which has been found only in eastern United States from New York to Tennessee, while *denticula* and *aureoviridis*, on the other hand, have been taken from New England, central United States and southern Canada, and *aspersa* is found in the Rocky Mountain region and westward. *Empoasca birdii* is limited to the North Central States and New England. A peculiar distribution is that of *snowi* which was described from New Mexico and the only other record is that from Wisconsin.

SYSTEMATIC POSITION AND PHYLOGENY

The genus *Empoasca* is included in the subfamily Typhlocybinae which is a member of the family Cicadellidae of the order Homoptera. Because of the small size of most of the species and the difficulty with which they are preserved the Typhlocybinae have not been studied to the same extent as many of the other members of the family. Van Duzee (1917) in his Catalogue of the Hemiptera of America north of Mexico lists thirty-two species of *Empoasca*. The present work includes thirty-six species and three varieties. The first attempt to treat the North American species in a systematic way was made by Gillette (1898) in his paper entitled The American Leafhoppers of the Subfamily Typhlocybinae in which he figures and describes sixteen new species of *Empoasca* and works out the synonymy for the American forms. *Chlorita* and *Kybos* were merged by him with *Empoasca* because the latter has priority and the characters separating these genera are not constant. Every gradation between the *Chlorita* and *Kybos* type of vertex and the differences in venation is often found in a single species and even in single individuals. The characters in this group are fewer and less constant than in most groups of leafhoppers. The shape of the face, vertex and genital pieces and the form and venation of the elytra are characters that have proved the most reliable. The markings are exceedingly variable, even within the same species, so that they cannot be relied upon with any degree of certainty throughout the genus as a whole. On the

other hand color pattern is quite constant for certain species or groups of species. Among the forms in which color pattern can be relied upon with considerable degree of certainty are *trifasciata*, *unica*, *atrolabes*, *birdii*, *smaragdula* and *unicolor*. In contrast with this the markings and color characters of such species as *mali* and *flavescens* are exceedingly variable and individuals which lack the characteristic markings of these species are identified with difficulty. For example, a hundred specimens of *mali* were examined by the writer and of these not more than seventy-five were well marked, the remaining twenty-five were ill-defined and separated from *flavescens* with difficulty. This is especially the case when the number of the spots of the pronotum is reduced from the typical number of six to three. *Unica* and *atrolabes* are closely related species as is shown both in their structure and in their color pattern. *Atrolabes* is not so definitely marked and can be separated from *unica* by a structural character, namely, the slight callosity beneath the eye. *Birdii* is recognized at once by the smoky bands on the elytra; poorly marked specimens would very likely be identified as *flavescens*. *Smaragdula* usually is separated with little difficulty because of the dark smoky median line; *unicolor*, which at first sight seems very poorly defined, possesses rather definite markings on the pronotum which makes its identification possible with a considerable degree of accuracy.

In separating all the species shades of green or yellowish green are a considerable aid to a person familiar with the genus. Unfortunately every one does not interpret color alike and many of the shades are beyond the power of accurate definition, so are of little or no use in written descriptions. The apple green color of *mali* and the slight touch of lemon yellow on the pronotum are aids in the identification of this species. The peculiar dark shade of green in *atrolabes* may be mentioned in this connection. In the same way in species like *obtusa* where markings are of doubtful value most of the forms can be separated at once by a person familiar with the group. Characters of this nature, however, have little value in keys and descriptions and may even be of doubtful scientific importance. For this reason the writer has attempted to correlate structural characters to supplement color pattern and size.

The shape of the vertex and its production beyond the margin of the eye serves as the best character for the division of the genus. Correlated with the produced acute vertex in forms like *mali* and *flavescens*, etc., is the wide range in distribution and al-

most omnivorous food habits. Forms of this type are included in the *Mali* group. Those forms which have bluntly rounded vertices, on the other hand, are placed in the *Obtusa* group, which so far as our records show are confined to woody plants. The wide range in food plants of species like *mali*, for example, is shown by the fact that this form is injurious to species of plants in such widely separated families as Betulaceae, Rosaceae, Leguminosae and Solanaceae, occurring on both woody and herbaceous plants. The food habits of *flavescens* have not been so carefully studied but it is known to be quite a general feeder. *Empoasca birdii* has considerable range in food habits as it occurs on hop, walnut, bean and a variety of weeds. This omnivorous habit is in striking contrast to such forms as *obtusa* and *aureoviridis* which as far as is known occur only on willow. Our knowledge of the food habits of the different species is not sufficiently complete to permit very definite statements regarding the groups as a whole.

GENUS *EMPOASCA* WALSH

Resembling *Dikraneura*, but with the marginal vein of the hind wing ending in a single apical cell. Vertex obtuse or angulate. Elytra long, lacking an appendix. Ocelli present. Slender species, usually green or greenish, sometimes unicolorous.

The genus *Empoasca* as thus defined may be readily separated from the genus *Alebra* Fieber by the fact that the latter has an appendix. The presence of two apical cells in the hind wing of *Dikraneura* separates it at once from *Empoasca*. The European genera *Chlorita* and *Kybos* of Fieber are superseded by *Empoasca*.

KEY TO THE GROUPS

- A. Vertex produced beyond the anterior margin of the eye less than half its dorsal length; apex bluntly rounded or obtuse. **OBTUSA GROUP**
 AA. Vertex produced beyond anterior margin of the eye at least one-half its dorsal length; apex more or less angulate. **MALI GROUP**

KEY TO THE SPECIES OF THE OBTUSA GROUP

- A. Elytra without color pattern, unicolorous.
 B. Pronotum at least twice as wide as long.
 C. Ultimate segment of female with distinct notch, general body color green *aureoviridis*
 CC. Ultimate segment of female without distinct notch, general body color whitish..... *pallida*
 BB. Pronotum considerably less than twice as wide as long.....
 D. Pronotum with a definite color pattern.....
 E. Clypeus constricted near point of juncture with the front *obtusa*
 EE. Clypeus of uniform width, not constricted..... *unicolor*
 DD. Pronotum without definite color pattern, sometimes mottled....
 F. Pronotum slightly mottled, ultimate segment of the female with U-shaped notch; distribution Eastern U. S..... *pergandei*

- FF. Pronotum without mottling, female with ultimate segment of the abdomen entire; distribution Western U. S. . . . *clypeata*
- AA. Elytra with definite color pattern or black spot.
- G. Elytra with black raised spot near the base of the fourth apical cell
- H. Sides of the pronotum roughly parallel. *incisa*
- HH. Sides of the pronotum not parallel.
- I. Vertex broadly rounded, not produced. *denticula*
- II. Vertex subangulate, produced about one-third its length.
- J. Slight callosity beneath eyes, body dull. *atrolabes*
- JJ. Eyes normal, body brilliantly colored. *unica*
- GG. Elytra without a spot near the base of the fourth apical cell.
- K. Elytra with one or more transverse bands.
- L. Vertex produced about one-third its length beyond the margin of the eyes *trifasciata*
- LL. Vertex not produced or at most less than one-third its length beyond the margins of the eyes. *pulchella*
- KK. Elytra without transverse bands.
- M. Elytra with definite white line along claval suture. *albolinea*
- MM. Elytra without definite white line on claval suture.
- N. With a dorsal median longitudinal stripe.
- O. Pronotum twice as broad as long, elongate species. *smaragdula*
- OO. Pronotum less than twice as broad as long, robust species. *vittata* n. sp.
- NN. Without dorsal median longitudinal stripe.
- P. Uniformly black, antennae white. *nigra*
- PP. Not uniformly black, antennae smoky.
- Q. Vertex produced about one-third its length beyond the anterior margin of the eyes, apex subangulate *osborni* n. sp.
- QQ. Vertex not produced, apex rounded.
- R. Ultimate segment of male sinuate. *livingstonii*
- RR. Ultimate segment of male with the posterior margin entire. *annella* n. sp.

KEY TO THE SPECIES OF THE MALI GROUP

- A. Vertex with the apex subangulate, more or less rounded.
- B. Front orange or red, rest of body varying from red to green.
- C. Elytra without markings. *coccinea*
- CC. Elytra with pattern or markings.
- D. Elytra with white dash on outer margin. *barbara* n. sp.
- DD. Elytra without markings on outer margins, white spot on corium. *morrisoni* n. sp.
- BB. Front without orange or red markings.
- E. Elytra with white vermicular markings. *alboscipita*
- EE. Elytra without vermicular markings, sometimes with white longitudinal lines. *robusta*
- AA. Vertex angulate, more or less sharply pointed.
- F. Pronotum three-fourths as long as broad.
- G. Pronotum with the sides roughly parallel. *nigroscuta*
- GG. Pronotum with the posterior portion considerably wider than anterior portion.

- H. Elytra with white nervures or more or less spotted... *aspersa*
 HH. Elytra with white nervures, without spots... *alboneura*
 FF. Pronotum less than three-fourths as long as broad.....
 I. Face tumid *tumida*
 II. Face not tumid.....
 J. Elytra not unicolorous
 K. Elytra with smoky transverse bands..... *birdii*
 KK. Elytra spotted or with longitudinal markings... *minuenda*
 JJ. Elytra unicolorous
 L. Scutellum with deep furrow..... *pura*
 LL. Scutellum without deep furrow.....
 M. Pronotum with longitudinal markings..... *radiata*
 MM. Pronotum with spots but not with longitudinal markings.
 N. With six or eight spots on the pronotum; male genitalia
 as in Fig. 22 *mali*
 NN. With three spots on the pronotum..... *viridescens*
 O. Face long and slender, length twice the width
 OO. Face normal, length less than twice the width.....
 P. Color yellowish green, length 3 mm; male genitalia
 as in Fig. 23 *flavescens*
 PP. Color greenish white, length 4 mm..... *snowi*

OBTUSA GROUP

Empoasca trifasciata Gillette

(Plate II, fig. 1)

This strikingly distinct species can be readily recognized by the three transverse reddish brown bands. Length, female 4mm; males 4mm.

Vertex short, less than one-half the width of the pronotum very slightly produced. Pronotum with lateral margins slightly angular. Width of the pronotum twice its length. Clypeus one-half the length of front.

Color.—Vertex varies from pale yellow to orange and in some forms is green-gold. Pronotum yellowish gold but usually with definite markings on the anterior one-third, posterior two-thirds mahogany color. Scutellum yellow or orange; elytra varying from green to pale yellow with two reddish brown transverse bands, one at the posterior third of the clavus, the other at the tip of the elytron. Front orange with light median longitudinal streak. Clypeus and genae green. Ventral surface of the abdomen light yellow or pale yellow.

Genitalia—Ultimate segment of female with slight emargination. Male, posterior end of abdomen, bluntly rounded.

Type specimen—U. S. National Museum.

Habitat.—Scattered records from New England, Middle Atlantic, and North Central States, west as far as Colorado and Arizona.

Host.—Cottonwood (Ball).

Empoasca smaragdula (Fallen)

(Plate II, fig. 2)

Resembling *aureoviridis*, but ultimate segment of the female with the posterior margin entire. Length, female 3.7mm; males 3.5mm.

Vertex not produced, about one-half its length beyond the margin of

the eyes. Front at most twice the length of the clypeus. A very slight constriction of the clypeus before the frontal suture. Pronotum about two and one-half times as wide as long.

Color.—Usually with a dark smoky line on the dorsum running the entire length of the insect, but in some forms obscure except along the claval suture of the wing. Vertex green or green-gold, in some forms entirely smoky. Pronotum entirely smoky or green, usually with a white median line. Front orange or smoky with a light median line. Clypeus, lorae and genae green.

Genitalia.—Ultimate segment of female with posterior margin entire.

Habitat.—Generally distributed throughout New England, Middle Atlantic, and North Central States, with scattered records from Tennessee, Colorado and California.

Hosts.—Willow (Baker); *Crotaegus rivularis* (Gillette).

This species is near to *aureoviridis*. The dark dorsal line is not mentioned in the original description, but is noted by Gillette.

Life History.—Adults were taken in August in Wisconsin and during June and July in Tennessee and Ohio.

Empoasca vittata n. sp.

(Plate II, fig. 3)

Resembling *smaragdula*, but much larger and more robust. Length, female 5mm.

Vertex not produced, apex broadly rounded. Pronotum less than twice as broad as long. Scutellum with a transverse groove near posterior third.

Color.—Vertex greenish yellow; margin of ocelli green. Pronotum and scutellum with a yellow median longitudinal line throughout. On either side of this line a broad, dark brown stripe, which begins from a point near the anterior margin of the pronotum and extends to the posterior end of the scutellum, where it unites to form a single stripe along the inner margins of the clavus. Inner border of apex dusky, remainder of elytra lemon yellow. Anterior margin and sides of the pronotum bright green. Front green with a light median stripe; clypeus green, tip bluegreen. Legs, ventral surface of thorax and abdomen light yellow. Pygofers and tip of the ovipositor blue-green.

Genitalia.—Ultimate segment of female with the posterior margin with a broad U-shaped incision.

Described from a single female taken at Stanford University, California, June 30, 1910. Type in DeLong's Collection.

Empoasca aureoviridis (Uhler)

(Plate II, fig. 4)

Of the same form as *obtusa*, but larger and the ultimate segment of female with a distinct notch. Length, females, 5mm; males 5mm.

Length of the vertex slightly less than twice the distance between the eyes, more produced than in *obtusa*. Pronotum not much more than twice the width of the vertex. Clypeus without constriction near point of juncture with the front.

Color.—Color ranges from golden yellow to green in different forms. Vertex gold or greenish. Pronotum usually with white markings near the

anterior border, rest of pronotum ranging from golden-yellow to green. Scutellum usually darker than pronotum with white longitudinal line running its entire length. Elytra green, hyaline at the tips, abdomen light yellow. Front variable, orange to bronze, sometimes with a light median longitudinal line. Clypeus green.

Genitalia.— Similar to *obtusa* but with a distinct notch on the lateral border of ultimate segment of the female; male plates stouter than in *obtusa* and not elongate.

Habitat.— Reported from Fort Collins, Palmer Lake and Marshall Pass, Colorado (Gillette). Specimens are at hand from Clarksville, Dyersburg, Bells and Paris, Tennessee, and Estes Park, Colorado (DeLong), and Sault St. Marie, Ontario (Osborn). Doctor Ball's collection contains specimens from Fort Collins, Ward and Rico, Colorado.

Host.— Willow (Gillette).

Life History.— Adults taken June and July in Tennessee and in August in Colorado.

Empoasca unicolor Gillette

(Plate II, fig. 5)

Resembling *mali*, but with the vertex not produced. Length, females 3.5mm; males 3.5mm.

Length of the vertex one-third the distance between the eyes. The front less than twice the length of the clypeus. Width of the pronotum one and one-half times its length.

Color.— Color varies in the different forms from green to yellowish green. Vertex yellowish green, in some individuals golden-green with a spot next each eye. Pronotum yellowish green with a dash in the middle of the anterior margin; scutellum pale green, a spot near the apex. Elytra unicolorous throughout varying from green to light golden-green. Ventral surface of abdomen yellowish green. Legs yellow. Tibiae and tarsi green.

Genitalia.— Ultimate segment of the female with the posterior margin with two oblique notches.

Type specimen.— U. S. National Museum.

Habitat.— Generally distributed throughout New England, Middle Atlantic and North Central States and southern Canada, scattered records from Colorado and Oregon.

Hosts.— Apple (Lathrop); *Crataegus coccinea* (Gillette).

Empoasca obtusa Walsh

(Plate II, fig. 6)

Resembling *aureoviridis*, but smaller and with the plates of the male genitalia more elongated. Length, females 3.7mm; males 3.5mm.

Vertex similar to *aureoviridis*, but not at all produced, bluntly rounded. Length of the vertex about one-half the distance between the eyes. Pronotum twice the length of the vertex with the angles rounded, two-thirds as long as wide. Clypeus with a constriction slightly below the suture separating it from the front; slight callosity below the eye.

Color.— Varying from yellowish green to pale green. Vertex golden yellow. Pronotum varies from pale yellow to green, somewhat mottled. Scutellum darker, usually with irregular white median longitudinal

streaks. Elytra green. Ventral surface of the abdomen light yellow, genitalia green.

Genitalia.—Female, similar to *aureoviridis*, ultimate segment smaller and less sinuate. Plates of the male more elongate than in *aureoviridis*, about three times as long as wide.

Type specimen destroyed in Chicago Fire.

Habitat.—Southern Canada, New England, Middle Atlantic, North Central States, south as far as Texas, west to California.

Hosts.—Willow (Gillette); *Betula lutea*, sheep laurel (*Kalmia angustifolia*); *Populus* sp. (Osborn).

Life History.—Adults taken June, July and August in New York, Tennessee and Wisconsin.

Empoasca unica (Provancher)

(Plate III, fig. 10)

Typhlocyba unica Provancher, Pet. Faune Ent. Can., Vol. 3, p. 340, 1890.

Empoasca splendida Gillette, Proc. U. S. Nat. Mus., XX, p. 731, 1898.

Resembling *atrolabes*, but larger and more brilliantly colored, and without a callosity beneath the eyes. Length, females 3.5mm; males 3.5mm.

Vertex slightly produced about one-fourth the distance between the eyes. Head as seen from the side with the front slightly rounded. Front narrow, about twice the length of the clypeus. Pronotum with angles rounded, the width about one and one-third times its length. Scutellum slightly shorter than pronotum.

Color.—Vertex bluish green with slight orange tint at apex. Anterior two-thirds of the pronotum reddish orange, remainder bluish. Scutellum reddish brown without markings. Elytra of the same color as the scutellum with a bright blue line extending along clavical suture, remainder of the elytra delicate light blue; tips hyaline with a black spot just in front of the cross-nervure of the inner apical cell. Ventral side of the abdomen yellowish with the genital segment greenish.

Genitalia.—Ultimate segment of female deeply emarginated; male genitalia one and one-half times length of valve.

Type specimen.—U. S. National Museum.

Habitat.—Described by Gillette from material collected by F. C. Pratt at Lakeland, Maryland; Lexington, Paris and Tullahoma, Tennessee; New Haven, Connecticut (DeLong); Kramer Mill Neck, New York (Osborn); Orangeburg, South Carolina (Lathrop).

Life History.—Adults taken in June (Tennessee) and in August and September (Connecticut).

Empoasca atrolabes Gillette

(Plate III, fig. 8)

Resembling *unica*, but smaller and less brilliantly colored and with a slight callosity beneath the eye. Length, females 3.5mm; males 3.5mm.

Length of the vertex slightly less than one-half the distance between the eyes. Pronotum broad, more than twice the length of the vertex, angles rounded. Front wider than in *unica* with clypeus less than twice the length of the front. Eyes with a slight callosity beneath.

Color.—Vertex greenish in some cases with a few light orange spots. Pronotum variable, reddish brown to dull gold. Scutellum darker than pronotum, dull gold or bronze, without markings. Elytra lighter in color than scutellum and a pale green line extending along the claval suture, remainder of the elytra yellowish green; tips hyaline; a decided black spot in front of the cross-nerve of the inner apical cell. Ventral surface of the abdomen yellowish.

Genitalia.—Ultimate segment of the female deeply notched at middle.

Type specimen.—U. S. National Museum.

Habitat.—Generally distributed throughout southeastern Canada, New England, Middle Atlantic and North Central States, west to Colorado.

Hosts.—*Corylus rostrata* (hazelnut), *Alnus viridis*, *Crataegus rivularis*.
Life History.—Adults taken in June and August in Wisconsin.

Empoasca albolinea Gillette

Resembling *unicolor*, but with a white line along the claval suture. Length 3.5mm.

This species appears to be very closely related to *unicolor*, resembling it very closely in size, form and color pattern. The external genitalia are also identical with those of *unicolor*.

Type specimen.—U. S. National Museum.

Habitat.—Virginia, Illinois, Kansas, Colorado and California.

Hosts.—Willow (Gillette).

Empoasca denticula Gillette

Resembling *pergandei*, but larger and without mottling on the pronotum. Length, females 4mm; males 4mm.

Vertex not produced, its length less than one-half distance between eyes. Pronotum three times length of vertex and about twice as wide as long, angles of pronotum acute. Clypeus nearly one-half as long as the front. As seen from the side the front is very rounding.

Color.—Pale yellowish green. Vertex gold or yellowish. Pronotum yellowish green. Scutellum the same color as the pronotum with a pale longitudinal stripe. Elytra pale green. Legs and ventral side of abdomen yellow.

Genitalia.—Plates of male elongate, about four times as long as broad.

Female, ultimate segment with a distinct notch on the posterior border.

Type specimen.—Cotype, U. S. National Museum.

Habitat.—Clarksville, Tennessee, Madison and Lake Geneva, Wisconsin (DeLong). Described by Gillette from specimens taken August 3, at Colorado Springs, and Fort Collins, Four-mile Hill (near Steamboat Springs) Colorado (Baker); Athens, Ohio (Osborn).

Life History.—Captures made June, July, August, in Colorado; July in Tennessee and in September in Ohio.

Empoasca pergandei Gillette

(Plate III, fig. 9)

Resembling *denticula*, but slightly smaller and with white mottling on the pronotum and vertex. Length, females 3.75mm; males 3.75mm.

Vertex produced less than half its length beyond the margin of the

eyes; length of the pronotum twice that of vertex. Greatest width of pronotum more than twice its length. Face as seen from the side very rounded, not pointed and as wide as long. Front more than twice the length of the clypeus.

Color.—General color yellow-green with considerable white mottling on pronotum and a white line running the length of the scutellum.

Genitalia.—The ventral ultimate segment of the female has a V-shaped notch.

Type specimen.—U. S. National Museum.

Habitat.—New Haven, Connecticut (B. H. Walden); Maine (Osborn); Washington, District of Columbia (Sanders). Described by Gillette from a female taken at Fort Hill, Massachusetts, July 4, 1890 (Theo. Pergande).

Life History.—Adults taken in July in Connecticut and in August in Maine.

Empoasca incisa Gillette

(Plate III, fig. 7)

Resembling *aureoviridis*, but with a deeper incision in the posterior margin of the female ultimate segment. Length, females 5mm; males 4mm.

Vertex not produced, length equal to two-thirds the distance between the eyes. Pronotum twice the length of the vertex, sides almost parallel, length two-thirds the width. Scutellum equal to the length of the pronotum. Front one and one-half times the length of the clypeus.

Color.—Vertex green. Pronotum green with two light marks, sometimes fused. Scutellum smoky with a white median longitudinal line. Elytra yellowish green. Front and clypeus green, abdomen light green.

Genitalia.—Ultimate segment of the female with a V-shaped incision. Ovipositor black.

Type specimen.—U. S. National Museum.

Habitat.—Brookings, South Dakota (H. C. Severin); Gillette described this species from Estes Park, Colorado; Bear Mountain, Vermont, Webster and Durham, New Hampshire (Osborn).

Life History.—July in South Dakota (H. C. Severin); Estes Park, Colorado, August 6 (Gillette).

Empoasca clypeata Gillette and Baker

(Plate III, fig. 11)

Resembling *obtusa* but with callosity beneath the eye. Length, females 4.5mm; males 4.5mm.

Vertex rounded but very slightly produced, length less than half the width between the eyes. Front similar to *obtusa*. Clypeus without constriction near the frontal suture; eyes with callosity beneath. Pronotum more than twice as long as the vertex, its width less than twice its length; angles rounded.

Color.—Bronze green with smoky tinge. Vertex green, pronotum and scutellum smoky. Elytra green with a smoky band along the claval suture, rest of elytra green. Front smoky, clypeus, lorae and genae green; legs blue.

Genitalia.—Width of male plates more than twice their length.

Type specimen.—U. S. National Museum.

Habitat.—Specimens are at hand from Knoxville, Tennessee (Cart-

wright, Ainslie); Estes Park, Steamboat Springs, Colorado (Gillette and Baker), June 10; Placer, California (U. S. Nat. Mus.).

Host.—Willow (Baker).

Empoasca livingstonii Gillette

(Plate III, fig. 14)

This species is recognized at once by its large size and deep smoky color. Length 4.25mm.

Vertex produced less than half its length beyond the margin of the eyes, apex rounded. Pronotum twice as broad as long and slightly more than twice the length of the vertex. Elytra with the nervures distinct at the cross-veins, but fading out towards the body, venation normal.

Color.—General color deep smoky to black. Front pale yellow with a more or less distinct line down the middle. Vertex unicolorous with the front. Pronotum smoky brown to blackish, with a subobsolete pale line along the middle. Scutellum concolorous with the pronotum, paler on the middle, the transverse groove black. Elytra unicolorous, deep smoky blackish, translucent. Feet pale yellow, abdomen more or less black above, yellow below.

Genitalia.—Posterior margin of ultimate segment of the female entire.

Cotype.—U. S. National Museum.

Habitat.—Carfield, Vancouver Island (C. Livingston); Easton, Washington, collected by Koebele (U. S. National Museum). Specimens examined in Dr. Ball's collection from Fort Collins, Colorado, and Duncan, British Columbia.

Empoasca osborni n. sp.

(Plate III, fig. 12)

Resembling *livingstonii*, but with the vertex more produced. Length, males 3mm.

Vertex produced beyond the margin of eyes about one-fourth its length. Distance between eyes twice the length of the vertex. Width of pronotum slightly greater than twice its length. Pronotum twice the length of the vertex. Head as seen from the side with vertex angular, eyes large. Front nearly two and one-half times the length of the clypeus. Face slightly broader than long.

Color.—General color smoky brown. Anterior edge of vertex with light brown markings, the rest smoky brown. Pronotum concolorous with vertex. Scutellum in some specimens with a white spot on the anterior median border. Elytra light smoky brown. Front brown with a light yellow longitudinal line. Clypeus brown shading to green at distal end. Lorae blue-green. Genae light yellow shading to green where it joins with the clypeus. Tarsi and tibiae blue-green. Ventral side of abdomen light yellow.

Genitalia.—Male, plates elongate, clothed with brown hairs.

Described from three males, type and paratypes, taken by Professor Osborn at Marietta, Ohio, September 13, 1905, and now in the Osborn collection.

Empoasca annella n. sp.

(Plate III, fig. 13)

This striking species resembles *osborni*, but is much larger. Length, male 5mm.

Vertex slightly produced, length less than one-third the pronotum. Front at least three times the length of the clypeus. Face longer than the width, much longer than face of *osborni*.

Color.—Dark bronze. Vertex rusty brown. Pronotum bronze with a yellow longitudinal median line extending the entire length of the pronotum and ending in a yellow spot at the posterior end of the scutellum. A parallel line on either side of the median line on the scutellum. Elytra smoky. Front light brown, with a light yellow longitudinal median line. Clypeus, lorae and genae light yellow. Ventral side of abdomen bright yellowish green.

Genitalia.—Ultimate segment of the male with the posterior margin entire, not sinuate.

Described from a single male taken in Estes Park, Colorado, collected August 25, 1920, by H. C. Severin. Type in Dr. DeLong's collection.

Empoasca nigra Gillette and Baker

This species is readily recognized by its small size and jet black color. Length 2.75 to 3.0mm.

Vertex not produced, apex rounded, disk of vertex sloping, with a slight median depression on the posterior half, opening into a slight depression on the anterior margin of the pronotum. Pronotum slightly less than twice as broad as long, anterior margin broadly rounded, posterior margin somewhat concave. Scutellum with a median pit in front of the transverse groove.

Color.—Black. Antennae whitish; ocelli surrounded by a narrow pale margin; elytra black, posterior third fading into smoky subhyaline; anterior tibiae and tarsi smoky.

Genitalia.—Posterior margin of male ultimate segment entire; of female, slightly notched.

Type specimen.—U. S. National Museum.

Habitat.—Mountains southwest of North Park, Colorado, collected by Baker; Little Beaver, Colorado (E. D. Ball).

Host.—*Artemisia tridentata* (Gillette).

Life History.—Adults taken in July.

Empoasca pulchella Gillette and Baker

Female.—Front and vertex without sculpturing, opaque. Length, 3mm.

Vertex slightly produced, about one-third its length beyond the anterior margin of the eyes. Clypeus a third longer than wide; lorae long and narrow. Pronotum about twice as wide as long, front margin rounded, posterior angles broadly rounded, sides without distinct sculpturing but with two small pits near the median line about one-fourth the distance from the anterior margin. Scutellum with a transverse groove.

Color.—Steel blue, varied with smoky and orange. Vertex with a brown median line on posterior two-thirds; ocelli rufous and distant from the eyes. Pronotum pale blue, washed with white and pale orange on the anterior margin. Scutellum orange with white mottling. Elytra subhyaline with three broad, distinct transverse bands. Clavus and corium posteriorly each with a pale orange stripe. Veins whitish apically.

Genitalia.—Ultimate segment of abdomen deeply notched, posterior angles rounded.

Type specimen.—U. S. National Museum.

Habitat.—Mountains southwest of North Park, Colorado, collected by Baker.

Host.—*Artemisia tridentata*.

Life History.—Adults taken July 10.

Empoasca pallida Gillette

Pale yellow species, almost white. Length 3.75mm. Vertex rounded, produced about one-third its length beyond the margin of the eyes. Pronotum with the length somewhat more than half the breadth.

Color.—Front pale yellow, mottled with ivory-white, genae and clypeus nearly white. Vertex yellowish with a median whitish line, on either side of this an opaque whitish line. Pronotum whitish, tinged with yellow and with one median spot on either side, one or two lateral light spots. Scutellum white with the tip and basal angles yellow. Elytra whitish, subopaque near the cross-veins, beyond the cross-veins transparent. Abdomen above and below yellowish white with the last ventral segment and the pygofers green. Legs whitish with tips of tarsi fuscous; tibiae and tarsi light green.

Genitalia.—Ultimate segment of female with the posterior margin sinuate.

Type specimen.—U. S. National Museum.

Specimens in U. S. National Museum labeled "Cotton, N. Car., June, 79."

MALI GROUP

Empoasca coccinea (Fitch)

Empoasca coccinea Fitch, Homop. N. Y. St. Cat., p. 63, 1851.

Typhlocyba coccinea (Fitch), Osborn, 20th Rept. N. Y. St. Ent., p. 544, 1905.

Empoasca coccinea (Fitch), Van Duzee, Cat. Hemip. N. A., p. 704.

This strikingly distinct species varies from light green to a bright red in different individuals. Length, females 3mm; males 3mm.

Pronotum emarginate, twice the length of vertex. Head as seen from the side rounded.

Color.—*Red form*—Vertex blood red, eyes pearly. Anterior two-thirds of pronotum red, posterior one-third mottled with gray. Scutellum red. Elytra tan. Front bright red. Distal end of clypeus blue-green. Tibiae and tarsi blue-green. Genae and lorae bright green at juncture with clypeus, remainder red. Abdomen yellowish green.

Green form.—Varying from light green to dark green. Sometimes with a touch of red or orange on the tip of the vertex. Front orange to deep red. Clypeus, lorae and genae blue-green as are also the tarsi. Elytra usually with a whitish line along the outer margin.

Genitalia.—Male, pointed, green color, crowned with hairs.

Habitat.—Cranberry Lake, New York (Osborn and Drake); Wanakena, New York; Patton, Pennsylvania; Harpswell, Grand Lake, Maine (Osborn).

Host.—White pine (*Pinus Strobus*).

Life History.—Adults taken in June in Pennsylvania and in August in New York and Maine.

Empoasca morrisoni n. sp.

(Plate IV, fig. 15)

Resembling *barbara*, but with the vertex more produced and with definite white markings. Length, females 3.4mm.

Vertex produced at least half its length beyond the anterior margin of the eyes. Pronotum less than twice as long as wide.

Color.—General color of the dorsal surface of the body light brown, with the borders of the pronotum, vertex and scutellum margined with green. A white spot on either side of the median line of the vertex, one on the median anterior border of the pronotum and scutellum. A large triangular spot on the anterior third of the corium. Tips of the elytra hyaline. An orange median line running two-thirds the length of the front. Clypeus, genae, lorae and the ventral surface of the abdomen yellowish green.

Genitalia.—Ultimate segment of female with the posterior margin entire.

Described from four females taken in a pine grove by Mr. Harold Morrison at Pacific Grove, California, May 29, 1915. Type in Morrison collection, paratypes in the Ohio State University and writer's collections.

Empoasca barbara n. sp.

(Plate IV, fig. 16)

Resembling *coccinea*, but larger and with a white dash on the outer margin of the elytra. Length, males 3.7mm.

Vertex rounded, produced one-half its length beyond the margin of the eyes. The width of the pronotum more than twice its length.

Color.—Vertex and pronotum pale yellow. Elytra pale cadmium yellow, outer margins with a dash of white. Front orange, clypeus, genae, lorae, blue; abdomen yellow. Tarsi and tibiae blue-green.

Genitalia.—Ultimate segment of male with a distinct V-shaped notch in the posterior margin.

Described from two males from Pacific Grove, California, collected by Mr. Harold Morrison, May, 1915. Type in the Morrison collection; paratype in the writer's collection.

Empoasca viridescens Walsh

(Plate IV, fig. 17)

Resembles *flavescens* and *mali*, but with a long slender face. Length, females 3mm; males 3mm.

Vertex slightly produced, less than half its length beyond the eye. Pronotum more than twice the length of the vertex. Face narrow and slender, length equal the width including the eyes; as seen from the side, angular. Front more than twice the length of clypeus.

Color.—Ranges from pale yellow to light green. Vertex with pale yellow spot near compound eye. Three white spots along the anterior border of pronotum. A white spot in center of pronotum and scutellum; in some cases the markings along the anterior edges of pronotum coalesce. Spots in center of pronotum and scutellum constant in all specimens examined, other markings often obscure or wanting. Face bright yellow,

flecked but often indistinct; tip of clypeus blue-green. Tarsi and tibiae blue-green. Abdomen pale yellow.

Genitalia.—Crescent-shaped notch along the posterior border of the ultimate segment of female.

Type specimen.—Destroyed in Chicago Fire.

Habitat.—Generally distributed throughout southern Canada and eastern United States, south to Texas, west to Oregon and Vancouver Island.

Life History.—Adults captured in April (Oregon) and in June (Massachusetts).

Empoasca pura (Stål)

Resembling *obtusa*, but with the vertex angulate and produced one-half its length beyond the margin of the eyes. Length 3.75mm.

Pronotum less than twice the length of the vertex. Scutellum with a deep median furrow.

Color.—Vertex orange, pronotum greenish yellow with a light spot on the median anterior border and a spot behind each eye. Scutellum yellowish, mottled with white. Elytra pale green. Front orange with distinct sculpturing. Clypeus, genae and lorae yellowish green; legs yellow; tarsi green.

Genitalia.—Ultimate segment of female with the posterior border entire.

Habitat.—Vancouver Island; Los Angeles, California; Long View, Catulla, Texas (U. S. National Museum).

Empoasca radiata Gillette

Pale yellowish green species, with more or less distinct longitudinal markings. Length 2.75mm.

Vertex produced at least one-half its length beyond the anterior margin of the eyes, its length contained in the breadth of the head two and one-half times.

Color.—Face pale yellowish green above, the clypeus deeper green. Pronotum pale green or yellowish with one median and two lateral greenish lines and two dorsal and two lateral orange-yellow lines. Scutellum pale greenish. Elytra dilute milky, the nervures whitish and with three more or less distinct orange colored lines, one on either side of the claval suture and another on the middle of the corium. Abdomen greenish yellow above and below. Legs whitish with the tips of tibiae and tarsi blue.

Genitalia.—Last ventral segment of female slightly produced and entire posteriorly.

Type specimen.—U. S. National Museum.

Habitat.—Horsetooth Gulch, Bold Mount, east of Estes Park, Colorado (Gillette); Victoria, Texas (U. S. National Museum).

Host.—Acacia (U. S. National Museum).

Life History.—Adults taken in Colorado in June and August.

Empoasca robusta Gillette

Small greenish yellow species, rather robust. Length, 2.75mm.

Vertex rounded in front and produced at least one-half its length beyond the anterior margin of the eyes. Pronotum three-fourths broader than long.

Color.—Face smoky ivory-white, without distinct markings. Pronotum whitish or yellowish white with two more or less distinct lemon-yellow longitudinal lines; slight spotting of the same color back of the compound eyes. Scutellum pale with lemon-yellow on the tip and base. Elytra whitish subhyaline, slightly smoky on the cross-vein, immediately before the cross-veins and beyond them transparent; the basal portion of the elytra slightly washed with lemon-yellow. Feet yellow, with the tibiae and tarsi of the second and third pairs greenish.

Genitalia.—Ultimate segment of female with the posterior border slightly notched.

Type specimen.—U. S. National Museum.

Habitat.—Nevada County, California (Gillette); Washington, District Columbia; Brewster, Texas (U. S. National Museum).

Life History.—Adults taken in September in California (Gillette).

Empoasca nigroscuta Gillette and Baker

(Plate IV, fig. 18)

This striking species ranges in color from almost pure white to almost solid black. Most specimens, however, are more or less whitish with smoky transverse bands. Length, females 3mm; males 3mm.

Vertex acute or strongly produced about one-half distance beyond the eyes. Pronotum almost twice as long as vertex; length three-fourths the width. Clypeus twice the length of the front.

Color.—In nearly all specimens examined the vertex is ashy-white, but occasionally smoky-white. Pronotum usually white, in the dark forms it is black. Scutellum black. Among the dark forms the elytra are smoky for the anterior two-thirds and a lighter shade the rest of the way. Usually there are two transverse smoky bands on the elytra, one near the posterior claval suture and another at the tip of the elytron; remainder of elytron ashy-gray. In dark forms, front smoky-white, with a dark longitudinal median line; clypeus, genae and lorae smoky; legs smoky. In light forms clypeus, genae, lorae and legs white.

Genitalia.—Ultimate segment of female with U-shaped notch.

Habitat.—Taken by Gillette, June 18 at Dolores and August 21, at Cerro Summit, Colorado; Estes Park, Colorado (Severin); Wasatch, Utah (Heidemann).

Host.—*Artemisia tridentata* (Gillette).

Life History.—Adults taken in Colorado in August.

Empoasca nigroscuta var. *typhlocyboids* Gillette and Baker

(Plate IV, fig. 19)

Same form as *nigroscuta*. Color much lighter and markings less conspicuous. Length, females 2.6mm; males 2.5mm.

Individuals vary from a pale green to a milky-white or bluish white. Face as seen from the side, very blunt. Vertex greatly produced, one-half its length beyond the eyes. Length of the pronotum two-thirds of its width, slightly greater than the length of the vertex.

Genitalia.—Female ultimate segment with a U-shaped incision on its posterior margin.

Type specimen.—U. S. National Museum.

Habitat.—Estes Park, Colorado, altitudes of 8500 feet and 8800 feet;

Fort Pierre, South Dakota (H. C. Severin); Steamboat Springs, Colorado, July 12, and Cerro Summit, Colorado, August 21 (Gillette).

Host.—*Artemisia tridentata* (Baker).

Life History.—Adults captured August, Colorado, and September, South Dakota (Severin).

Empoasca snowi Gillette

(Plate IV, fig. 20)

Resembling *mali* very closely, but larger and of a greenish white color. Long slender species with almost uniform color throughout. Length, females 4mm; males 3mm.

Vertex very much pointed, produced one-half its length beyond the eyes. Length of the pronotum equal to that of the vertex, width three-fourths its length. Front very narrow. Clypeus less than one-half the length of the front. Head as seen from the side bluntly rounded.

Color.—Vertex gold-yellow with a greenish spot on either side of the median line. Pronotum yellowish in some specimens with three distinct whitish spots along the anterior border. Elytra pale green, tips hyaline. Front gold-yellow shading to green toward the clypeus; clypeus and legs green. Lower surface of abdomen light yellow.

Genitalia.—Ultimate segment of female with very slight incision. Male genitalia pointed; ultimate segment with a slight notch.

Type specimen.—U. S. National Museum.

Habitat.—Lake Geneva, Woodman and Madison, Wisconsin (DeLong). Described by Gillette from two female specimens collected by Prof. W. A. Snow at Magdalena Mountains, New Mexico, August, 1894; specimens in U. S. National Museum marked "Ariz."

Life History.—Adults taken in Wisconsin, June, July and August, and in August in New Mexico.

Empoasca aspersa Gillette and Baker

(Plate IV, fig. 21)

Empoasca aspersa Gillette and Baker, Van Duzee, Cat. Hemip. N. A., 1917.

Length, females 3mm; males 3mm.

The vertex is produced one-half its length beyond the margin of the eyes. Pronotum slightly more than twice the length of vertex. Width of pronotum not quite twice the length. Front three times the length of the clypeus. Sharply angled as viewed from the side.

Color.—Vertex yellowish green. Pronotum bluish gray with minute dark scattered spots. Elytra same color, but with larger and more definite spots. Wings hyaline. Front yellowish green mottled with black spots. Clypeus, lorae and genae green. Legs blue-green.

Genitalia.—Ultimate segment of female with a distinct U-shaped notch.

Habitat.—Fort Collins, Sept. 27 (Gillette); in mountains southwest of North Park, July 10, and at Steamboat Springs, Colorado, July 12 (Baker); Los Angeles county, California, March, U. S. National Museum (Gillette); Wasatch, Utah, June, 27 (Heidemann); Lehi, Utah (Sanders).

Empoasca tumida Gillette

Pale greenish yellow species with face very tumid. Length, 2.50mm.

Vertex produced about one-half its length beyond the margin of the

eyes. Pronotum not wider than the head, less than twice as wide as long. Front very tumid.

Color.—Front ranging in color from almost entirely yellow to almost entirely green, the upper part yellow. Vertex yellow to greenish, with a median and two lateral longitudinal pale lines which are sometimes indistinct in the greener specimens. Pronotum pale green with five whitish spots on the anterior margin and in well marked specimens there are three ill-defined pale lines which are continuous with the pale lines of the vertex. Abdomen yellowish green above and below. Legs yellow, tarsi bluish.

Genitalia.—Ultimate segment of female slightly produced with posterior margin entire.

Type specimen.—U. S. National Museum.

Habitat.—Horseshoe Gulch, Fort Collins, Colorado (Gillette); Santa Barbara, California (F. Winterstein).

Host.—Plum (Gillette). Probably accidental.

Life History.—Adults taken in June in Colorado, and in September in California.

Empoasca mali (LeBaron)

(Plates I, IV, fig. 22)

Resembling *flavescens*, but with six or eight spots along the anterior border of the pronotum and differing in internal genitalia of male. Length, females 3mm; males 3mm.

Vertex angulate, produced more than half its length beyond the margin of the eyes. Pronotum twice as broad as long, and less than twice the length of the vertex.

Color.—General color yellowish green. Vertex green, flecked with white spots. Pronotum lemon yellow with a series of six or eight white spots along the anterior border. Scutellum typically has an "H" shaped spot near the center and a white spot at the posterior angle. In some forms the spots on the pronotum and vertex are indistinct. Elytra are yellowish green. Dorsal and ventral surface of the abdomen light green. Tarsi and tibiae blue-green. Eyes pearly-white during life but becoming brown after death.

Genitalia.—Ultimate segment of female without notch along posterior margin. Male genitalia shown in figure 22 of Plate IV.

Habitat.—This species is generally distributed throughout the United States east of the Rocky Mountains.

Hosts.—Because of the confusion of other closely related species with *mali* and the accidental captures made on plants on which it does not normally feed, the long list of host plants of this species probably will be considerably reduced when our knowledge of its feeding habits is more accurate. The species of leafhoppers confused with this form in economic literature are: *E. unicolor* and *E. flavescens*. The observations of the writer indicate that *mali* may occur on a number of widely separated plants. Among the economic hosts on which reproduction takes place and hopperburn occurs are: potato, bean, sugar beet, hemp, raspberry and apple. It attacks white birch and other ornamentals. A decided preference to potato, beans, clover, alfalfa and beets, in order named, was noted.

Life History.—There has been considerable disagreement regarding

the number of generations a year. The writer's experiments in Iowa covering a period of four years show two generations for that latitude. In the spring the adults come out of their hiding places under old leaves and trash where they have spent the winter and feed on curly dock and other weeds. As soon as early potatoes have attained a good growth, the hoppers leave the weeds and fly to them. They feed on the tender foliage and begin to insert eggs inside the leaves and stems. In about two weeks the eggs hatch into nymphs which feed on the undersides of the leaves, causing them to roll up and burn. Of the two broods, the first appears on early varieties of potatoes in June and July, while the second is abundant and destructive to late varieties in August and early September.

Empoasca flavescens (Fabricius)

(Plate IV, fig. 23)

Resembling *mali*, but with very indistinct markings on the pronotum. Length, females 3mm; males 3mm.

Vertex angulate, produced more than half its length beyond the margin of the eyes. Pronotum more than twice the length of the vertex. Face as seen from the side, rounded. Head very small. Front less than twice the length of the clypeus.

Color.—Yellowish green. Vertex yellow without markings, pronotum light green, in well marked specimens with a dash of white along the anterior median border, one back of the center of each eye. Elytra yellowish green, hyaline at tips. Front with indistinct light longitudinal line. Eyes brown, clypeus, lorae and genae green. Tarsi and tibiae bluish green, tip of abdomen light green.

Genitalia.—Ovipositor extends slightly beyond the tip of the abdomen. Ultimate segment of female without notch along posterior margin. Plates of the male acute, angular.

Habitat.—Generally distributed throughout the Middle Atlantic, North Central and Southern States with scattered records from New Mexico and California.

Life History.—Adults taken in June, July, August and September in Tennessee.

Empoasca minuenda Ball

Empoasca minuenda Ball, Proc. Bio. Soc. Wash., Vol. 34, pp. 23-24, 1921.

Pale green, very small, vertex angulate. Length 2mm.

Vertex produced at least one-half its length beyond the margin of the eyes. Anterior edge of pronotum broadly rounded. Pronotum twice as wide as long, slightly larger than vertex. Elytra long, resembling *mali* in shape; first apical cell very broad and extending nearly one-third its length beyond the base of the second cell; third cell variable, usually small and triangular.

Color.—Ranging from a pale lemon yellow to golden yellow with scutellum tinged with orange and white. Tip of ovipositor brown above. Prunose white area in some specimens midway on the costa.

Genitalia.—Ultimate segment of female moderately rounded posteriorly, margin entire. Male plates long, triangular, the attenuate tip curved upward, rounded at the apices.

Type specimen.—Dr. E. D. Ball's collection.

Habitat.—Collected by G. F. Moznette at Miami, Florida (Ball).

Host.—Avocado (Ball).

***Empoasca minuenda* Variety *moznettei* Ball**

Empoasca minuenda var. *moznettei* Ball, Proc. Bio. Soc. Wash., Vol. 34, p. 24, 1921.

Size and form of *minuenda*, golden or lemon yellow, with a variable number of oval black spots. Pronotum with a widely separated pair of spots, scutellum with a larger and adjacent pair and a similar pair on the first three or four abdominal segments. Each elytron usually with six spots, three on the costa, two on the claval suture and one on the corium.

Type specimen.—Dr. Ball's collection.

Habitat and host the same as *minuenda*.

***Empoasca minuenda* Variety *clavigerana* Ball**

Empoasca minuenda var. *clavigerana* Ball, Proc. Bio. Soc. Wash., Vol. 34, p. 24, 1921.

Of the same form and color as variety *moznettei*, but with additional markings. Two dark brown stripes extending from just back of the vertex margin across the pronotum, scutellum and along the inner margin of the elytra. Stripes on vertex narrow and definite, separated by about their own width; on the pronotum they usually widen and rarely fuse, on the scutellum they usually fuse. In light examples the stripes are interrupted, appearing as elongate spots on the vertex and pronotum.

Type specimen.—Dr. Ball's collection.

Habitat and host the same as *minuenda*.

***Empoasca birdii* Goding**

Resembling *flavescens*, but of a brighter color, bright yellow with the wings smoky and the vertex rounded. Length, females 3mm; males 2.5mm.

Vertex angulate, produced one-half its length beyond margin of eyes. Pronotum twice the length of the vertex. Front more than twice the length of the clypeus. Face broader than in *flavescens*.

Color.—In general, light yellow with elytra smoky, pronotum light yellow, sometimes smoky. Scutellum smoky with a light line running its length. Elytra in some specimens smoky, in other specimens with two to three transverse smoky bands; rest of the elytra pale yellow. Front bright yellow with a white longitudinal median line. Clypeus, lorae and genae light yellow. Tarsi, light yellow, abdomen pale yellow.

Genitalia.—Ultimate segment of the female with a broad U-shaped notch. Male genitalia pointed.

Specimen presumably type material in U. S. National Museum.

Habitat.—Marshfield, Wisconsin; Taylor Falls, Minnesota; Wooster, Magnetic Springs, Columbus, Ohio (Osborn); Yuma, Arizona (Morrisson); Agricultural College, Michigan (Prof. Davis); Urbana, Illinois (Forbes and Hart); Rutland, Illinois (Goding); Ithaca, New York (Cornell University).

Hosts.—Apple, hop, walnut, beans and weeds (Goding).

Life History.—Adults taken in May at Columbus, Ohio, and in August in Wisconsin and Minnesota.

Empoasca alboneura Gillette

Resembling *unicolor* but with the vertex produced beyond the anterior margin of the eyes, more than half its length. Length, females 3mm; males 3mm.

Length of the vertex two-thirds the distance between the eyes. Pronotum twice as long as vertex, length three-fifths its width. Head as seen from the side, angular, with the front rounded. Clypeus two-thirds as long as the front, genae extend almost to the tip of the clypeus.

Color.—Pale greenish yellow. Vertex with a light longitudinal median line with two light spots near the posterior edge. Pronotum the same color as the vertex. Light median longitudinal line running the length of the pronotum and scutellum. A light line running from anterior to posterior edge of pronotum back of the center of the eye. Elytra and ventral side of abdomen light green. Tarsi and tibiae blue-green. Front, clypeus, lorae and genae greenish.

Genitalia.—Ultimate segment of female with a U-shaped notch along the posterior border.

Type specimen.—U. S. National Museum.

Habitat.—Scattered records of this species have been noted from the Middle Atlantic States, Tennessee, Mississippi, Texas, Ohio, Nebraska, Kansas, Colorado and California.

Life History.—Adults taken June, July, August and September in Tennessee, Pennsylvania and Colorado.

Host.—Plum (Gillette). This may be accidental.

Empoasca alboscripta Van Duzee

Van Duzee describes this species as follows:

"Size and aspect of *alboneura*; elytra with somewhat vermiculate or areolate white markings. Length 3 to 3.5mm.

Vertex rounding, but little produced; about two-thirds the length of the pronotum. Elytra subhyaline toward their apex with strong nervures, last ventral segment of the female long, elliptical, subangular and entire at the apex.

Color.—Yellowish green, becoming darker or olive green above but still with a yellow tint. Elytra usually touched with bluish at base of the clavus and washed with the same color near its apex. Vertex with the median line and a spot either side pale. Pronotum with the median line and a spot behind each eye pale. Scutellum with a pair of pale diverging discal lines which are frequently wanting. Elytra when fully colored with the inner nervures and some connecting spots whitish, outlining in an irregular way several elongate green arcoles: four on the clavus of which two are basal, one is median and one apical, and a row of three long ones on the inner margin of the corium. Membrane faintly smoky-hyaline with green nervures and a row of whitish spots on either side of the transverse nervures. Wings hyaline, highly iridescent, the nervures white. Beneath touched with blue, green on the clypeus and legs. Margins of the venter stronger yellow, the tergum lined with dark green." (Trans. San Diego Soc. Nat. Hist., Vol. 2, p. 56, 1914.)

Habitat.—San Diego and LaJolla, California (Van Duzee).

Host.—*Ceanothus* sp.

Life History.—Adults taken in April, June and January in California. Two specimens collected by Harold Morrison at Santa Barbara, California, and apparently belonging to this species are at hand.

Species not Included

Empoasca maligna (Walsh). Walsh, Bost. Soc. Nat. Hist., Vol. 9, p. 317, 1864. Woodworth regards this species as identical with *obtusa*.

Empoasca malefica (Walsh). Walsh, Bost. Soc. Nat. Hist., Vol. 9, p. 317, 1864. This species probably is identical with *viridescens*.

Unfortunately the types of the above species were destroyed in the Chicago Fire so the question of their validity remains unsettled. It is impossible to recognize them from Walsh's brief descriptions.

THE APPLE LEAFHOPPER (*EMPOASCA UNICOLOR* GILLETTE).

The importance of *unicolor* as an apple pest has not received general recognition owing to the fact that until very recently economic entomologists failed to associate its injury with this species. The damage done to apple foliage by *Empoasca mali*, *E. unicolor* and *Typhlocyba rosae* has generally been lumped together under the ill-defined term apple leafhopper and accredited to *E. mali*, the most widely known form of the three. These three species are members of the sub-family Typhlocybinae which includes the smallest leafhopper known and, as the group is a difficult one taxonomically, it is not surprising that economic writers have confused the forms and in many cases failed to associate the injuries with their respective species. It is unfortunate that this is the case, as it makes of little or no value a mass of otherwise carefully collected data and has caused considerable confusion in the literature.

HISTORY

In 1898 Gillette described *unicolor* as a new species from specimens sent him by Cornell University and taken at Salineville, Ohio, a number of individuals from Michigan Agriculture College on apple collected July 15, by Professor Davis, and some material collected by himself on *Crataegus coccinea* near Fort Collins, Colorado. For a number of years the species seems to have been recognized only by specialists. Van Duzee (1906, 1908) reports it from Quebec, Ontario, New York and Ohio.

Webster (1908) found in apple bark at Albert Lea, Minnesota, some eggs which he believed to be those of *mali*, but which were very probably those of *unicolor* or *rosae*. They measured 4mm by .75mm, and were found in the previous year's growth in three year old apple trees.

The eggs found by Ainslie which Washburn (1908) mistook for *mali* are much too large and probably belonged to some Membracid.

Parrott (1909) collected from apple foliage three species of leafhoppers which were identified by Van Duzee as *mali*, *rosae* and *unicolor* and separated definitely for the first time the three species occurring on apple.

Osborn (1915) finds at Orono, Maine, *unicolor* on arborvitae and white pine.

According to Childs (1918) *unicolor* is less widely distributed in Oregon than *rosae*.

The first study of the biology of this species was made by Lathrop (1918) at Geneva, New York, in which he establishes the main points in the life history of the three species. He very carefully distinguishes between the injuries and correlates them with their proper species, and finds that apple is the only host, that there is one generation a year and that the eggs are laid in the fall in apple bark.

DESCRIPTION OF THE INSECT

Adult. — The adult is of a bright green color. There is a spot on each vertex near the eye, a longitudinal stripe down the middle, and an ill-defined mark on the outer border of the pronotum. The scutellum bears a spot near its apex. The ultimate segment of

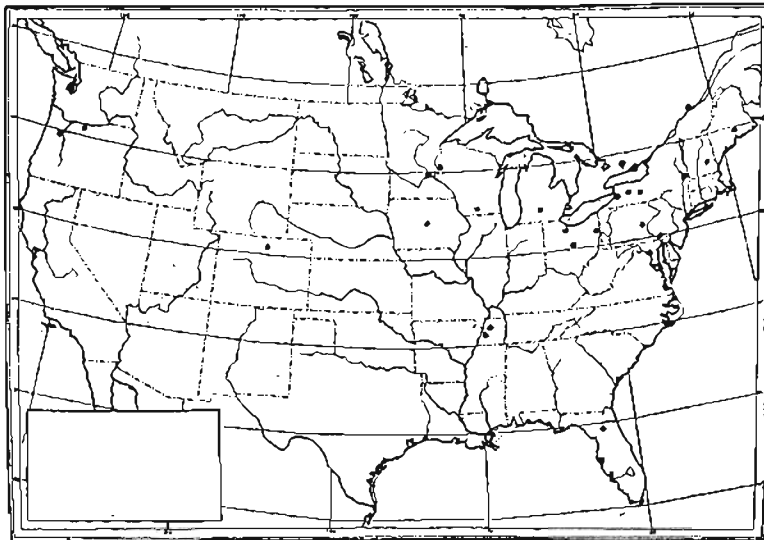


Fig. 4. Map showing the distribution of *Empoasca unicolor*.

the female has a median incision from which arises a toothlike projection. The adults of *unicolor* are slightly larger than those of *mali*.

Eggs. — The eggs are deposited in the previous year's growth in the bark of apple and appear as raised blisters. Lathrop (1918) found that the eggs of this species are never laid in leaves, which indicates that the winter is passed in this stage.

Nymphs. — The nymphs are bright green, their color becoming darker with age. The vertex, sides of the pronotum and wing pads are yellowish. There is a dark green dorsal median longitudinal stripe on the abdomen.

DISTRIBUTION

Empoasca unicolor is generally distributed throughout southern Canada and eastern United States. As shown by the accompanying map its area of greatest abundance is the New England, Middle Atlantic and North Central States. It occurs also in Colorado and Oregon. While it was not listed from Kansas by Lawson (1920), it is known to occur in Iowa and Minnesota.

HOSTS

Apple and *Crataegus* appear to be the hosts favored of this species. Osborn reports it on conifers in Maine. It is known to occur on apple in New Hampshire, New York, Ohio, Michigan, Minnesota, Iowa and Oregon.

HABITS AND INJURY

The apple leafhopper, both in the nymphal and adult stages, confines its attack to the under sides of the leaves. It feeds very largely on the older leaves and may occur on both old and young trees but usually prefers the latter. The injury is very similar to that produced by *Typhlocyba rosae*, the affected leaves showing characteristic white stippling of the upper surface. The spots appear at first as isolated points along the midrib and margin of the leaf. As the severity of the attack increases these coalesce and the entire leaf becomes whitish.

Probably the most serious injury from an economic standpoint is the spotting of the fruit. These leafhoppers constantly emit droplets of liquid from the anus which collects in minute spots forming specks of dark green or black which injures the quality of the fruit. This is especially the case during dry weather or when there is insufficient rainfall to thoroughly wash the fruit and leaves.

Egg punctures may occur in sufficient numbers to cause injury to the twigs by allowing fungi to enter. It has not been definitely established that *unicolor* transmits fire blight (*Bacillus amylovorus* Burrill) but investigations conducted by Lathrop (1918) have implicated *mali* and further study may show that *unicolor* also is responsible for the spread of this plant disease.

LIFE HISTORY

On May 28, 1919, apple trees at Ames, Iowa, were found infested with the apple leafhopper. The nymphs were practically all of the first instar, although a few were in the second. By June 4, most of the nymphs were in the second instar but a few were found that were in the fourth and fifth.

In 1920, first instar nymphs were collected May 24, while in 1922 they were observed on May 13. During these years the writer was making a life history study of *mali* and a careful watch was kept to learn the time of appearance of *unicolor* in correlation with aforementioned species.

On June 3, 1922, many of the nymphs of this season had reached the fifth instar but a few individuals of the second and third instars could still be found. The leaves showed a considerable amount of stippling and a few adults were taken.

LENGTH OF NYMPHAL LIFE

During the summer of 1922 the writer conducted several experiments on the life history of this species. While every phase in the life cycle has not been fully worked out the data collected throw light on certain phases which are of value in the study of the biology of the species. On May 11 a number of apple branches were placed in the greenhouse to hatch nymphs. The first individuals appeared on May 13. In all sixty nymphs were hatched from these branches and removed to vials where they were reared on apple leaves. A careful record was kept of the moults and the dates adults emerged. The mortality was high so only twenty adults were reared. The comparative length of time spent in

TABLE I. COMPARATIVE LENGTH OF NYMPHAL INSTARS

STAGE	NO. INSECTS OBSERVED	MIN. DAYS	MAX. DAYS	AVERAGE
1	10	2	2	2
2	6	2	3	2
3	5	2	5	3
4	4	3	5	3.5
5	12	2	6	3.2
Total	37	11	21	13.7

the various nymphal stages is shown in the following table which is a summary of the results obtained in these breeding experiments. It is shown that it requires an average of 13.7 days for the nymphs to reach maturity, with a minimum of 11 days and a maximum of 21 days.

The above table is based on averages from a number of individuals. It has been observed by the writer and others who have conducted life history work that a mere mathematical average of instars does not always represent the actual life history. While a considerable number of moults were observed it was difficult to follow individual nymphs from the time of hatching until they reached the adult state. At this time the writer was interested in life history studies of *mali*, which was the main project under consideration so that little time could be spent on the perfecting of technique for a study of *unicolor*, the same methods being applied in this work as in the study of *mali*. It was found difficult to keep apple leaves fresh in vials, and not feasible to rear them on the trees in leaf cages so that the mortality in cage experiments was much higher than with *mali* under similar conditions. The following table gives the complete data from the hatching of the egg until the emergence of the adult of two individuals:

TABLE II. INDIVIDUAL RECORD OF NYMPHAL STAGES AT AMES, IOWA, 1922

NUMBER	DATE OF HATCHING	FIRST MOULT	FIRST STAGE DAYS	SECOND MOULT	SECOND STAGE DAYS	THIRD MOULT
1	May 23	May 25	2	May 27	2	June 1
2	May 19	May 20	1	May 22	2	May 24

NUMBER	THIRD STAGE DAYS	FOURTH MOULT	FOURTH STAGE DAYS	FIFTH MOULT	FIFTH STAGE DAYS	TOTAL NYMPHAL PERIOD DAYS
1	5	June 4	3	June 7	3	15
2	2	May 27	3	May 30	3	11

LIFE CYCLE

It requires an average of a year for the apple leafhopper to complete its life history. Of this period from seven to eight months are spent in the egg stage, for it is in this condition that the insect passes the winter. About the middle of May the eggs hatch, and the nymphs continue to emerge and develop during May and June. By the first week in July all the nymphs have reached maturity. The adults may be found on apple foliage during the sum-

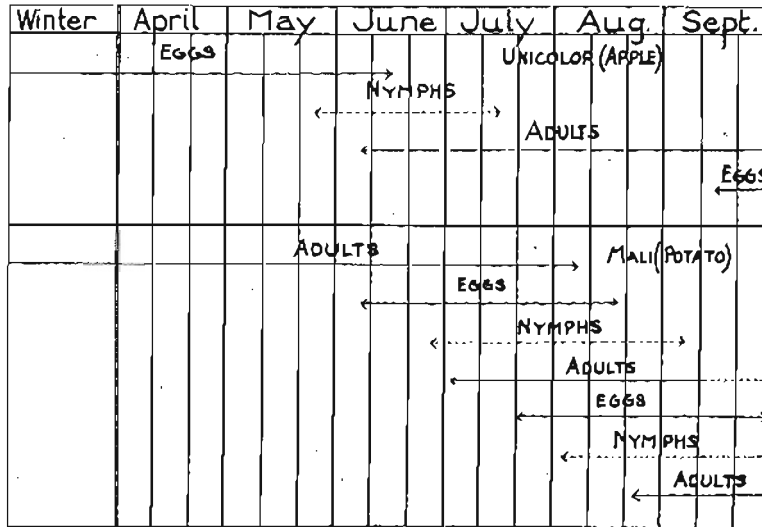


Fig. 5. Life histories of the apple leafhopper (*E. unicolor*) and the potato leafhopper (*E. mali*). Ames, Iowa.

mer. During the summer of 1920 a number of adults were collected in an apple orchard on July 8. Practically all the nymphs had disappeared by this date. These adults were introduced into a cage on a small apple tree and observed throughout the summer. A close watch was kept for evidence of egg-laying and the appearance of second generation nymphs. Although adults lived as late as the first week in September in this cage no young were produced. This indicates a single generation a year and confirms the observation of Lathrop in New York. Some of these adults lived sixty days in captivity. The first eggs of *unicolor* were found during the first week in September and straggling adults were found during the fall up to the time of frost. Apparently they are unable to pass the winter in this stage.

TABLE III. DATES ADULTS EMERGED IN BREEDING CAGES, AMES, IOWA, 1922

MAY				JUNE								TOTAL				
24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	
2	4		1	4		2		1			1		2	1	2	20

The above table gives the dates adults emerged in breeding cages. In the field this period was extended from the middle of May to the first week in July. The average length of time required by *Empoasca unicolor* to complete its life cycle is shown in

the following table. The period will vary considerably with the season but the following table represents approximately the life cycle during a normal year.

TABLE IV. AVERAGE LIFE CYCLE OF *EMPOASCA UNICOLOR*, AMES, IOWA

Egg Period.....	8 Months
Nymphal Period.....	5 Months
Preoviposition Period.....	3.5 Months
	12.0 Months

THE POTATO LEAF HOPPER (*EMPOASCA MALI* LeBARON)

As already mentioned in the introduction, the life history studies of this species were conducted by Dr. Fenton and the writer at Ames, Iowa. The completed results of this investigation will appear as a bulletin* of the Iowa Agricultural Experiment Station. Owing to the inadvisability of repeating detailed discussions of methods and experiments here, only the general conclusions are given in this paper, with such data as are necessary for obtaining a comprehensive knowledge of the biology of the species. The reader is referred to the above-mentioned bulletin for a complete account of our knowledge regarding the relation of *mali* to hopper-burn and for the more technical phase of the life history.

HISTORY

The earlier records of this species have been as an apple insect, but recent investigation has shown that potato is the favorite host plant. Both the insect and the injury have been much confused with species of widely different habits so that the earlier economic literature must be read with considerable caution. Among the species that have been commonly mistaken for *mali* are *unicolor* and *flavescens*. Because of the large number of references in which the identity of the species is questionable, the reader in reviewing the literature finds it difficult and in some cases quite impossible to determine with what species the reference deals.

LeBaron (1853), who described this species under the name of *Tettigonia mali*, calls attention to its injury to apple foliage in Illinois. The first notes on the biology were published by Forbes (1884), who observed that the adults hibernate and the eggs are laid during early summer in apple leaves. He was the first to mention the curling and browning of apple leaves that had been

* Since the preparation of this dissertation the bulletin to which reference is made, "Bionomics and Control of the Potato Leafhopper" (Iowa Agr. Exp. Sta. Res. Bull. 78, July, 1923), by Doctor Fenton and the writer, has been published.

injured by the leafhopper. Osborn (1896) first records it as a pest of potatoes and describes it as producing a serious wilting of early varieties. The task of untangling the literature during the decade of 1900 to 1910 becomes increasingly difficult owing to the confusion of *unicolor* and *Typhlocyba rosae* with *mali*. Parrott, fortunately, differentiated between the forms occurring on apple and showed conclusively that the earlier workers had been in doubt regarding these species. This was followed by the work of Lathrop (1918) to whom belongs the credit of bringing order out of chaos and establishing definitely the main facts in the life histories of the three species. According to his observations *mali* has two generations a year in the latitude of New York and hibernates as an adult. On the other hand, *unicolor* passes the winter in the egg stage in the bark of apple and has but a single generation, while *Typhlocyba rosae* produces a second generation on apple, but winters in the egg stage mainly on roses.

The first clue to the cause of tipburn was a series of experiments conducted by Dr. Ball (1918) in Wisconsin, which have already been referred to, in which he showed that *mali* is responsible for the greater part of burning of potato foliage and proposed the name hopperburn for the injury to potato vines.

Ackerman (1919), working in southeastern Pennsylvania, on the importance of this species to apple nursery stock, found that there is no evidence of the winter being passed in the egg stage, as was commonly supposed to be the case.

Life history studies conducted by Dr. Fenton and the writer have aided in clearing up a number of disputed points in regard to the biology of this insect. Brief summaries of these results have been published. The species was found to be two brooded in Iowa (Fenton and Hartzell, 1920, Hartzell, 1921).

Beyer (1922) reports six generations a year on beans in Florida and states that the egg-laying period extends from March to December.

DESCRIPTION OF THE INSECT

Adult. — The adult, or mature potato leafhopper, is a pale green insect about one-eighth of an inch in length. The pronotum bears along its anterior border from six or eight white spots, in well marked specimens. These markings are quite variable in number and arrangement. In addition to these spots there is a more or less distinct "H" pattern on the scutellum.

Eggs. — The eggs are laid in slits in the veins and stems of potato plants and to some extent in the leaves and petioles of apple,

bean and other host plants. Upon hatching, the tissue around the incision dies and forms a small sunken area which is quite noticeable on close examination and marks the previous location of the egg.

Nymphs. — At first the nymphs are so small and resemble the leaves so closely that they are scarcely visible. They pass through five stages of growth, developing wings in the adult state.

DISTRIBUTION

The potato leafhopper is widely distributed throughout the United States and southern Canada east of the Rocky Mountains. It has been reported from the West Indies and South America. The writer has examined specimens in Professor Osborn's collection from Guatemala and Bolivia. It is known to occur in Florida but probably reaches its greatest destructiveness in the Upper Mississippi Valley where its relative abundance during a season is the determining factor as to whether a good or a poor crop of potatoes will be harvested. This species apparently does not occur on the Pacific coast although forms from that region have been referred to it.

HOSTS

The insect feeds quite generally and has been reported from a large number of plants. The more important hosts on which reproduction takes place and hopperburn occurs are potatoes, beans, sugar beet, hemp, raspberry and apple. Among the ornamentals it attacks birch. *Mali* probably feeds on plants that will not sustain its young. The adults have been kept alive for some time on bluegrass. This omnivorous habit of the adult has had much to do with lengthening its list of host plants. It seems to prefer potatoes, beans, clover, alfalfa and beets in order named, but a seasonal difference is shown in the relative abundance on different hosts. Among weeds, curly dock (*Rumex crispus* L.) serves as the chief food supply to adults emerging from hibernation. If potato fields are near, they leave the weeds and begin egg-laying in the potato vines, where all stages will be found during the summer. During the latter part of the growing season when the vines dry up the remaining adults return to curly dock, where they are present until frost, after which they enter into hibernation. This weed serves as a link in the food supply from the time late potatoes die in the fall until early potatoes reach a suitable size the following spring. The writer succeeded in rearing a complete generation on curly dock in breeding cages.

HABITS

The seasonal migration of the adults from weeds to potatoes occurs at the time the plants are about six inches above ground. Correlated with it is the sexual maturity of the adults, high humidity and a temperature of about 70° F. Again in the fall when the late potato vines have dried up there is a dispersal to curly dock, where they remain until frost, after which the second generation adults enter into hibernation. During cool weather the adults are inactive and cling to the under sides of the leaves. In warm weather they fly up in clouds when disturbed. Most of the injury is caused by the nymphs sucking the juice from the plants and transmitting hopperburn. The nymphs are usually found on the under sides of the leaves near the midrib or small veinlet. When first hatched they are pale yellow in color, but upon feeding take on a green tint. This, in addition to their small size, makes them difficult of detection. As they grow older they become more active, they run swiftly and dodge from one surface of the leaf to another when disturbed. A nymph usually remains on the leaflet where it hatched until forced to migrate because of the drying up of the leaflet as the result of feeding and hopperburn. As the season advances and the disease progresses, migration of the nymphs from plant to plant and even from one row to another is not uncommon.

There has been considerable confusion in the literature regarding the stage in which *mali* hibernates because of the confusing of this species with others of different habits. After the excellent work of Lathrop (1918) this difficulty is not encountered as he shows very plainly that *E. mali* hibernates in the adult stage. The writer has kept adults alive in the greenhouse as late as December, and Beyer, working in Florida, was able to keep them in cages all winter. In Iowa the adults appear from hibernation during April and May where they have been found on curly dock and various weeds. The spring migration takes place about the first week in June.

LIFE HISTORY

Overwintering adults are present in the field as late as the last week in August. Since these individuals spend the winter in hibernation the longevity of these forms is in the neighborhood of eleven or twelve months. There is an overlapping of broods from the middle of July until the end of the growing season. In order to be certain that the individuals used in our cage experiments were not of mixed ancestry, all life history experiments were conducted with individuals of known pedigree. The summer generation and

second generation adults were reared from nymphs to eliminate the possibility of confusing the broods. The longevity of summer generation adults averaged about forty-five days. The males have a short life in comparison to the females, with an average of seventeen days.

The eggs are laid in the leaf tissue of potato and apple and other plants. As the ova are very minute it was found impossible to make counts directly. Fertile females were placed in cages on unexposed plants and the number of nymphs that hatched daily was counted. The maximum number of young produced by a single female was one hundred forty-eight. Under favorable conditions a female will average one or two eggs per day. The period of oviposition is relatively long, for in nearly all cases the females laid eggs within a day or two of death. The period varies from about a month for the overwintering females to a little over two months for the summer generation.

The length of time spent in the nymphal stage depends very largely on temperature. In July only a week is required, while in October with cooler weather the period is prolonged to three or four weeks.

Considerable time is required for *mali* to complete its life cycle. In Iowa the minimum time was about four weeks and the average seven weeks. The comparatively long period to complete a generation precludes the possibility of the species being many brooded in the latitude of Iowa. Breeding experiments were conducted during the three years the study was in progress, with two broods appearing each year and no indication of a third brood.

The chief natural enemies of *mali* are an egg parasite (*Anagrus armatus* Ashm.) and a fungous disease (*Entomophthora sphaerosperma*). Neither one is of sufficient importance to keep the insect under control.

LITERATURE CITED

The reader is referred to Van Duzee's (1917) Catalogue of Hemiptera of America north of Mexico for the literature which deals with the synonymy of the genus *Empoasca*. The citations included here are additions since the above named catalogue was published, together with the more important contributions to the economic literature of the genus.

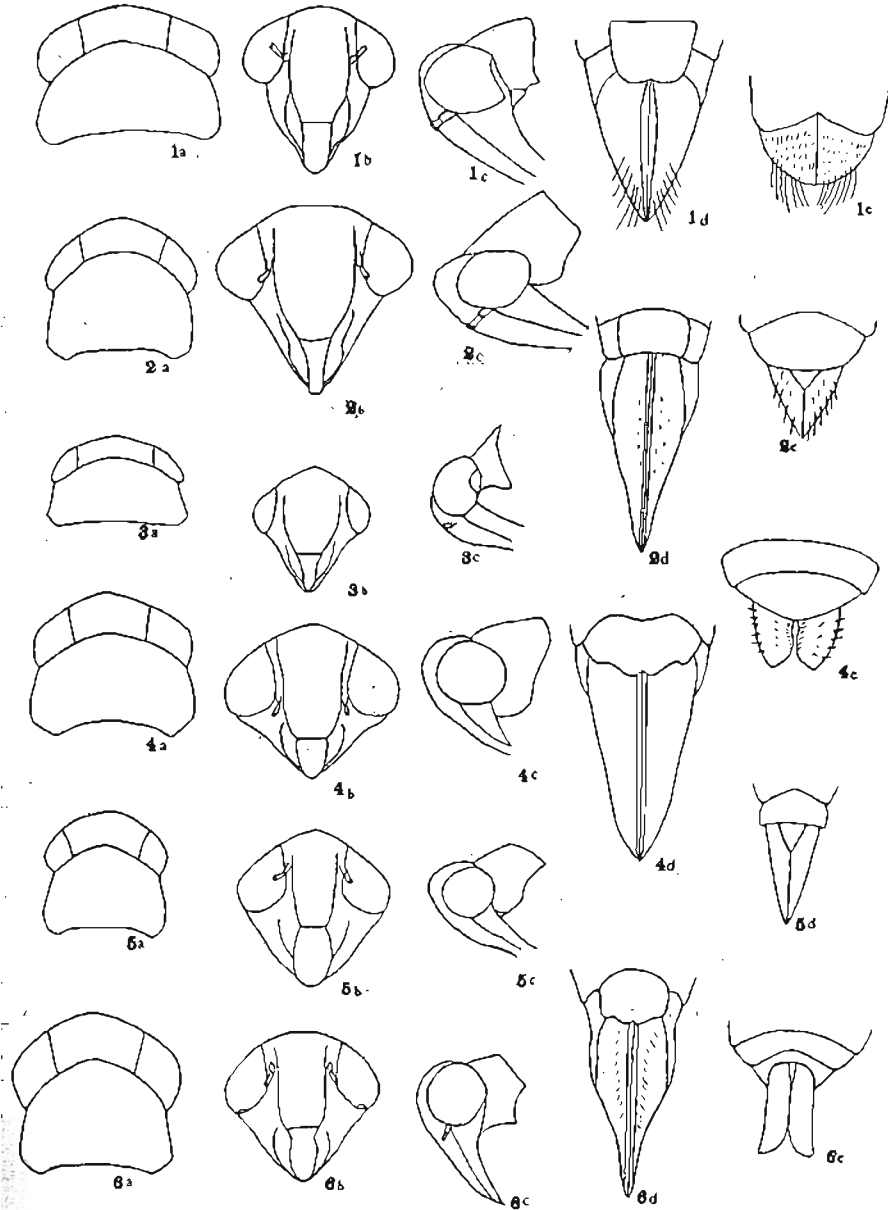
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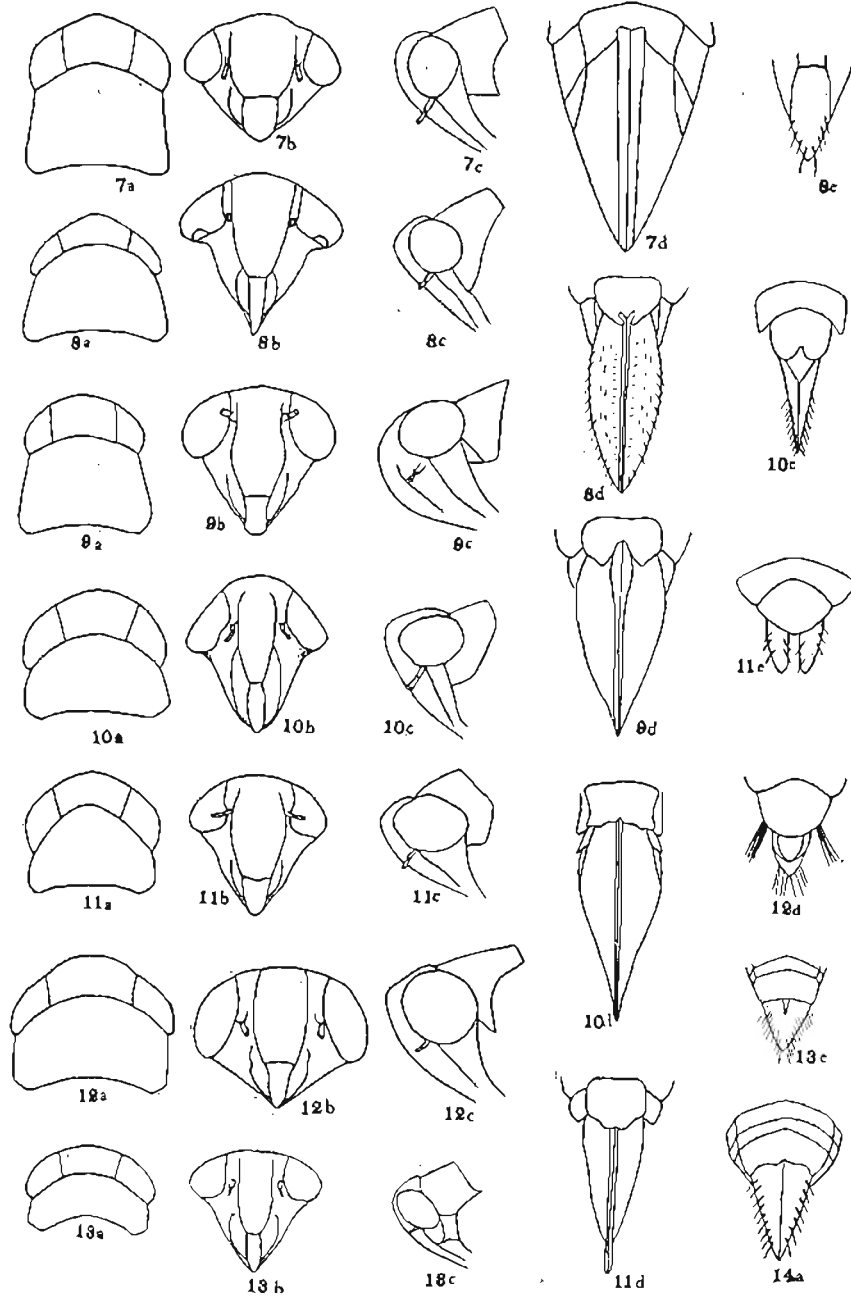
EXPLANATION OF PLATE II

- Fig. 1. *Empoasca trifasciata* Gillette. a. Head and pronotum. b. Front. c. Side view of head. d. Female genitalia. e. Male genitalia.
- Fig. 2. *Empoasca smaragdula* (Fallen). a. Head and pronotum. b. Front. c. Side view of head. d. Female genitalia. e. Male genitalia.
- Fig. 3. *Empoasca vittata* n. sp. a. Head and pronotum. b. Front. c. Side view of head.
- Fig. 4. *Empoasca aureoviridis* (Uhler). a. Head and pronotum. b. Front. c. Side view of head. d. Female genitalia. e. Male genitalia.
- Fig. 5. *Empoasca unicolor* Gillette. a. Head and pronotum. b. Front. c. Side view of head. d. Male genitalia.
- Fig. 6. *Empoasca obtusa* Walsh. a. Head and pronotum. b. Front. c. Side view of head. d. Female genitalia. e. Male genitalia.



EXPLANATION OF PLATE III

- Fig. 7. *Empoasca incisa* Gillette. a. Head and pronotum. b. Front. c. Side view of head. d. Female genitalia.
- Fig. 8. *Empoasca atrolabes* Gillette. a. Head and pronotum. b. Front. c. Side view of head. d. Female genitalia. e. Male genitalia.
- Fig. 9. *Empoasca pergandei* Gillette. a. Head and pronotum. b. Front. c. Side view of head. d. Female genitalia.
- Fig. 10. *Empoasca unica* (Provancher). a. Head and pronotum. b. Front. c. Side view of head. d. Female genitalia. e. Male genitalia.
- Fig. 11. *Empoasca clypeata* Gillette and Baker. a. Head and pronotum. b. Front. c. Side view of head. d. Female genitalia. e. Male genitalia.
- Fig. 12. *Empoasca osborni* n. sp. a. Head and pronotum. b. Front. c. Side view of head. d. Male genitalia.
- Fig. 13. *Empoasca annella* n. sp. a. Head and pronotum. b. Front. c. Side view of head. d. Male genitalia.
- Fig. 14. *Empoasca livingstonii* Gillette. a. Male genitalia.



EXPLANATION OF PLATE IV

- Fig. 15. *Empoasca morrisoni* n. sp. a. Head and pronotum. b. Front. c. Side view of head. d. Female genitalia.
- Fig. 16. *Empoasca barbara* n. sp. a. Head and pronotum. b. Front. c. Side view of head. d. Male genitalia.
- Fig. 17. *Empoasca viridescens* Walsh. a. Head and pronotum. b. Front. c. Side view of head. d. Female genitalia.
- Fig. 18. *Empoasca nigroscuta* Gillette and Baker. a. Head and pronotum. b. Front. c. Side view of head. d. Female genitalia.
- Fig. 19. *Empoasca nigroscuta* variety *typhlocyboidea* Gillette. a. Head and pronotum. b. Front. c. Side view of head. d. Female genitalia.
- Fig. 20. *Empoasca snowi* Gillette. a. Head and pronotum. b. Front. c. Side view of head. d. Female genitalia. e. Male genitalia.
- Fig. 21. *Empoasca aspersa* Gillette and Baker. a. Head and pronotum. b. Front. c. Side view of head.
- Fig. 22. *Empoasca mali* (LeBaron). a. Lateral view of male genitalia. b. Dorsal view of connective and oedagus. c. Dorsal view of style.
- Fig. 23. *Empoasca flavescens* (Fabricius). a. Dorsal view of connective and oedagus. b. Dorsal view of style. c. Female genitalia. d. Ventral view of male genitalia. e. Lateral view of male genitalia.

